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ABSTRACT

This activity book was developed because of the importance of understanding both our water resources and the impact of global change. The materials in this set were designed to use current data and information access skills, offer productive collaboration experiences, and provide critical science decision-making opportunities. Activities are grouped into the following categories: Great Lakes in perspective, global climate change, Great Lakes climate factors, visualizing changes in the Earth system, biodiversity: bird populations, biodiversity: forest ecosystems, biodiversity: nonindigenous species, biodiversity: Great Lakes fish, life support for an aging lake, estuary values and changes, toxic chemicals and global change, agriculture and climate change, Great Lakes shipping and lowered lake levels, recreation: where will we play?, and environmental response. (MKR)

Great Lakes Instructional Materials for the Changing Earth System

An Earth Systems Education effort of the Ohio Sea Grant College Program and The Ohio State University

Sea Grant

Great Lakes Instructional Material for the Changing Earth System

(GLIMCES)

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and the 224-page *GLIMCES* are available for $9.00.
For quantity orders, phone 614/292-8949 for additional price information.

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The Ohio Sea Grant College Program is one of 29 state programs that works to increase understanding and wise use of the nation's ocean and Great Lakes resources for the public benefit in partnership with government, academia, and industry. Sea Grant fulfills its mission through promoting education excellence, responsive research and training, and broad, prompt dissemination of knowledge and technical information.

OHSU-EP-080

CONTENTS ◆

◆ *GLOBAL CHANGE IN THE GREAT LAKES*

Great Lakes Instructional Materials for the Changing Earth System:

Integrative Activities on Global Change

In 1992 the Ohio Sea Grant Education Program produced a set of *Scenarios* depicting scientists' best estimates of how the Great Lakes region will be affected by global change. We defined global change as environmental modification on a planetary scale, emphasizing the impacts of atmospheric changes on the hydrological, biological and lithospheric components of regional systems. In all the *Scenarios*, human uses of Great Lakes resources were emphasized, because the region is the home for 30.7 percent of the U.S. population and one in three Canadians (External Affairs and International Trade Canada, March 1993). Dependence on water resources is reflected in our economy, culture, and history, as well as in our understanding of interactions in the Earth system.

This activity book was developed because of the importance of understanding both our water resources and the impact of global change. Scientific, political, and social experts have established an agenda for research on global change (U.S. Global Change Research Program, 1993), and inherent within it is the importance of developing an informed leadership and public awareness of issues. Sea Grant research among the region's teachers has also indicated a need and desire for Great Lakes education materials that address current environmental topics and are ready for classroom use.

The materials in this set were designed to use current data and information access skills, to offer productive collaboration experiences, and to provide critical science decision-making opportunities.

Global change issues bring to education

1. a reason for integrating the sciences
2. a need for incorporating social concerns in science teaching
3. a demand to develop collaborative working styles that draw on the diverse skills of all stakeholders in an issue.

The educators and scientists who produced this volume of *Great Lakes Instructional Materials for the Changing Earth System* hope it will provide GLIMCES (pronounced "glimpses") of potential changes. Our goal is that the lessons learned will allow people to make those lifestyle decisions that will contribute to an environment in which changes are improvements.

Glimpses of GLIMCES: Activity Abstracts

The Great Lakes in Perspective

With this activity, students will investigate data that make each of the Great Lakes unique. They examine human population densities, fish populations, shorelines, and water volume. Base groups and expert groups first predict the numbers for each lake and then examine the actual data. Students learn of the distribution of resources throughout the Great Lakes region and consider how to measure the value of those resources. They will make a list of the things they value about the Great Lakes and will consider whether these things have a price.

Global Climate Change

The goal of this set of activities is to help students have a greater appreciation of the potential for climate change in a modern world. In the first activity, students work in groups and graph a portion of global and Great Lakes temperature anomaly data sets. They then make predictions for future years based on each data set. The class combines the data and observes how their predictions compare to the actual observed readings. A study of climate change continues as students observe historical changes in levels of greenhouse gases. In the next section a laboratory experiment demonstrates the effect of greenhouse gases on the atmosphere. The last activity examines the continuous debate over the evidence for global warming. Students decide if the level of certainty warrants a policy decision.

Great Lakes Climate Factors

These activities examine the climate of the Great Lakes region. In the first activity students investigate lake levels, comparing monthly, seasonal, and yearly changes to precipitation for the same time period. The next theme involves seasonal drought. Students examine drought, precipitation, and temperature maps for interrelationships and trends. WorldWideWeb sites provide up-to-date as well as historic climate information.

Visualizing Changes in the Earth System

Students play a "More or Less" game to identify the impact of changes resulting from global climate change. In the next activity students imagine a personal experience by one of the Great Lakes and use art to portray their ideas. Students examine cartoons and comics that deal with Great Lakes scenarios and environmental topics in order to describe, interpret, and classify these important communication tools. Students then compose their own cartoon. After completing these activities, students will be able to locate and interpret environmental editorial cartoons and will discuss how cartoons communicate environmental information.

Biodiversity: Bird Populations

In this set of activities, students investigate the effect of climatic changes on wildlife populations. Birds are one of the most observed types of wildlife in surveys conducted by amateurs and professionals. In this activity, the data from two surveys are used and interpreted. Students examine how temperature affects the range of a bird species and how metabolic rates vary depending on bird ranges at different latitudes. Surveys such as the Christmas bird count provide a method of investigating population trends for different species. Students are challenged to determine whether this knowledge can be used as evidence for global climate change.

Biodiversity: Forest Ecosystems

Using a plot survey format, this outdoor activity has students mark off three different size plots, nested within each other. In each plot the students identify and inventory trees within a specific height range. This illustrates one way in which ecological studies are done to predict future dominant ecosystem species, and to make predictions on future dominant species if maples migrate from the forests. When students are finished they will be able to identify a sugar maple and associated species of a maple forest, locate on a map the general area where sugar maples are found today, and understand the potential effects of global climate change on sugar maple populations.

Biodiversity: Nonindigenous Species

Students match a set of cards describing eight different Great Lakes invaders with the species' method of introduction, country or region of origin, and impact of their introduction into the Great Lakes ecosystem. They then examine potential impacts of global warming on the invaders. Extension activities suggest discussion, research, and activity to further the students' understanding of the impact of exotics.

Biodiversity: Great Lakes Fish

Students construct a map of the Western Basin of Lake Erie showing the spawning and nursery areas for 11 fish species. They then determine which of those areas would remain intact if global warming causes the water level to drop. The effects on fish populations and human uses of fish are discussed. Students also examine the thermal range of the fish species to determine if the fish species are presently at either the northern or southern limit of their temperature range and where the fish could migrate if the water temperature increased.

Life Support for an Aging Lake

Students learn about the effects of global warming on the aging process of the Great Lakes. A lab activity with Euglena demonstrates the effects of phosphorous on the growth of a lake organism at present lake temperatures and projected lake temperatures with global warming. Dissolved oxygen levels are explored at various water temperatures. After completing these activities, students will be able to explain how increased water temperature affects population growth, compare the effects of phosphorous on an organism at higher water temperatures, explain the effects of increased water temperature on dissolved oxygen, and hypothesize a possible impact of global warming on aquatic life in the Great Lakes.

Estuary Values and Changes

This set of activities examines some of the unique characteristics of estuaries. Students will explore the impact of an estuary on nutrients entering a lake by observing sequential changes in phosphorus and nitrogen concentrations following a storm event. They will list sources of nutrient inputs to Lake Erie and explain how wetlands can improve water quality. Through a simulated estuary plankton sample the students can consider the importance of microorganisms in an aquatic community, observe seasonal changes in populations, and predict the effects of some human and environmental forces on conditions in an estuary. The third activity allows students to consider how global warming might affect wetlands along a lake. Students create a vertical profile of an area of wetlands using bathymetric map data. They determine whether new areas along a shoreline would be shallow enough to support a potentially migrating wetland and discuss what is needed for shorelines in general to migrate as a response to global warming.

Toxic Chemicals and Global Change

This set of three activities examines the problem of airborne toxins in the Great Lakes region. In activity A, small teams of students investigate the sources and health effects of several airborne pollutants. By examining the cause of the emissions, students brainstorm ways in which levels of toxins can be diminished. Students also investigate the amounts of and distance that toxins travel through the air by examining data and creating an air current model. Activity B concentrates on the accumulation of toxins in fish fat with a lab demonstration using iodine and vegetable oil. Students also learn which types of fish to avoid eating and how to prepare fish to avoid consuming the toxins. In Activity C, students construct a food chain, demonstrating the bioaccumulation of toxins as they progress through the food chain.

Agriculture and Climate Change

Students work in groups to study the effects of global climate change on agriculture in the Great Lakes region. From maps of the present and future Corn Belt students make calculations of changes in acreage and crops grown in light of global warming. Important factors help in the prediction of the future, such as how increased CO_2 would alter photosynthetic rates, how change in water supply would affect soils, and how a longer growing season might affect insects as well as the plants themselves. From this activity, students will understand what some current Great Lakes crops are and how global climate change could affect their production. They will also hypothesize about the economic impact on crops grown in the region.

Great Lakes Shipping and Lowered Lake Levels

Students solve several mathematical problems to calculate the effects of global climate change on the Great Lakes shipping industry. Calculations determine the effects of various changes in lake levels, as well as profits and changes in prices of consumer products. After finishing this activity, students should be able to calculate the net worth of a vessel's cargo, determine the loss in revenue for ship owners if lake levels drop, and understand how much of our economy relies on the shipping industry. Students will also consider the effects of global warming on coastal communities. They will determine how much the shoreline will move in two harbors in the region, draw new shorelines, and measure the change in land area.

Recreation: Where Will We Play?

A role play activity allows students to portray individuals with different perspectives on how global warming will affect the Great Lakes region's recreation industry. Roles represent two distinctly different business interests – those who believe global warming will occur and want to build a summer resort, and those who do not believe warming will occur and want to build a winter resort. Other students represent community members. After completing this activity, students will be able to locate recreation areas on the Great Lakes and recognize the interdependence of resources, climate, and the recreation industry. They will understand that the issue can be viewed from two perspectives, discuss the potential economic impacts of global warming, and list potential changes in recreational opportunities on the Great Lakes. Finally, they will make recommendations for recreation managers to adapt to the possibility of climate change.

Environmental Response

Students consider what they believe is the most appropriate response to global climate change. In the first activity, advertising ideas are generated through brainstorming. Students create ads that demonstrate how people can accept, abate, or adapt to global climate change. They are encouraged to create messages and ads that could influence environmental choices of others and ultimately impact global change in the Great Lakes region. In the second activity the class examines one of many energy use choices made every day, that of driving a car. The car is on trial for producing CO_2 which causes global warming. Data are presented as well as opinions from the air, a CO_2 expert, teenage driver, and the car itself. The jury decides what is to be done and explores the likelihood of implementing its solution in society.

Using *Great Lakes Instructional Materials for the Changing Earth System*

Each of the *Global Change in the Great Lakes Scenarios* is addressed through at least one activity in this set. An accompanying matrix on page IX which matches activities to *Scenarios*, the Earth Systems Understandings (ESUs), and the Earth subsystems directly addressed (hydrosphere, lithosphere, biosphere, atmosphere) demonstrates the range of instructional opportunities available for the classroom.

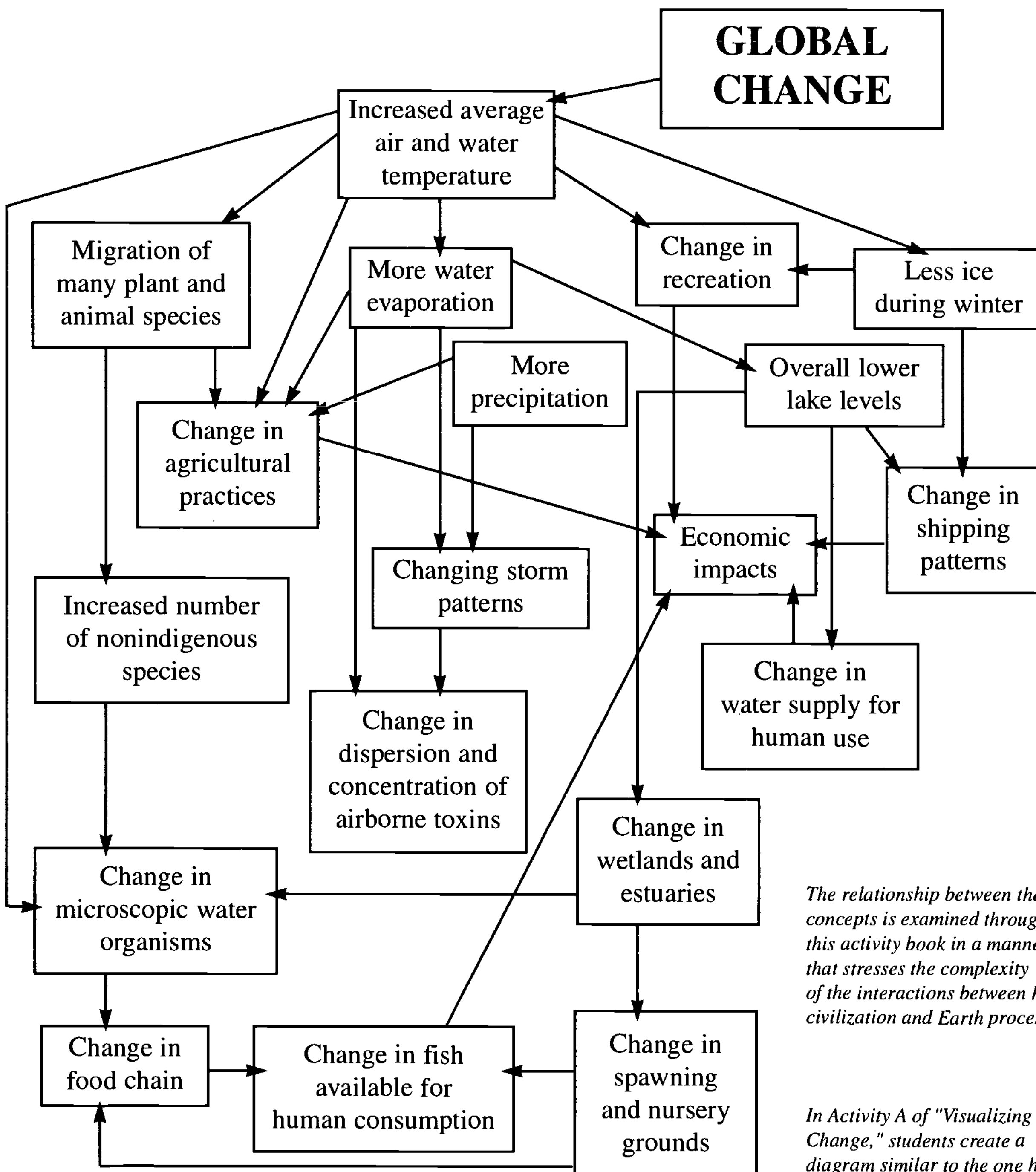
The principles that guided development of the activities should also direct their classroom use:

- potential for collaborative learning and group decision-making
- use of historical and descriptive as well as experimental data
- integration of science disciplines in a social context.

It is recommended that the format for the activities be retained when they are used in the classroom. Some short activities are designed for introduction to topics or for awareness. Longer activities focus attention for extended work and are designed to build understanding, synthesis, application, and evaluation skills.

1. Each activity is a question to be explored. Far too many classroom activities are done for the sake of activity alone. If an important and relevant question is the guide for the learning, there is greater focus and a readily apparent reason for doing the activity. Be sure to call students' attention to the question driving the exploration.
2. Activities are accompanied by the *Global Change in the Great Lakes Scenarios*, which may be duplicated as needed for student background.
3. Most activities are addressed to the teacher, that is, they are most useful as guides for experiences rather than recipes for students' direct use. Additional notes and answers are found in narrow columns on each page so they can be concealed if the page is actually to be given to students.

The Predicted Effects of Global Change on the Great Lakes Region



The relationship between these concepts is examined throughout this activity book in a manner that stresses the complexity of the interactions between human civilization and Earth processes.

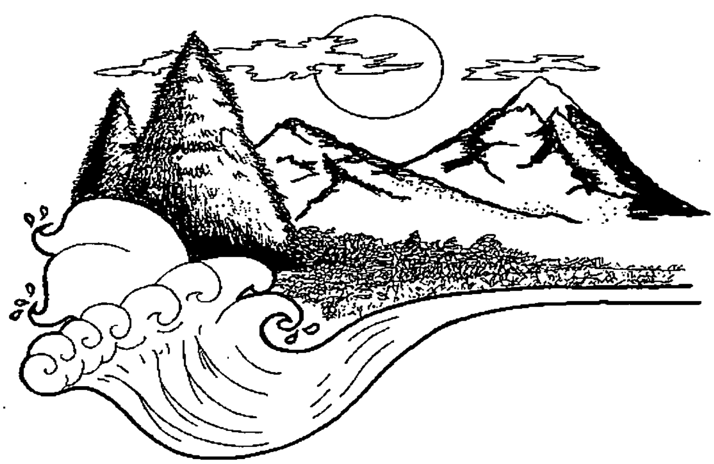
In Activity A of "Visualizing Change," students create a diagram similar to the one here. This encourages them to consider many of the consequences of global change.

Making Connections

There is always a danger in producing curriculum materials designed for infusion: How can we facilitate getting new material into the existing flow of classroom subject matter? In this project we have designed several kinds of connections to assist teachers in finding not only the place where the new materials fit, but also the justification for fitting them and the ancillary resources that can contribute to their effectiveness. The connections we see are demonstrated here and in the charts on the following page for:

- Earth Systems Education
- National Science Education Standards
- Benchmarks for Science Literacy

Earth Systems Education



Earth Systems Education is a program of curriculum restructure in which teachers take responsibility for critical evaluation of their science curriculum, including content, classroom processes, learner outcomes, and assessment, and strive to make changes that create a curriculum more responsive to human needs and future quality of life. The process of change is assisted by scientists and science educators through development of materials such as these. Earth systems education is based on integration of traditional science disciplines for a more comprehensive understanding of the interactions of Earth subsystems: the hydrosphere, lithosphere, atmosphere, and biosphere.

Efforts are guided by a Framework of seven Understandings (next page) developed by science teachers, science educators, and scientists to represent fundamental desired results of all of science education. Each activity in this set addresses a number of the understandings and two or more Earth subsystems, and includes suggestions for extending learning.

As a major topic of Earth Systems Education, global environmental change has been addressed by a number of efforts supported by NSF and the Ohio Sea Grant Education Program. The Global Change in the Great Lakes *Scenarios*, included in this set, synthesize the types of changes the region can expect with a doubling of CO_2. In combination with the Earth Systems Understandings (ESUs), the *Scenario* references provide both a rationale and background information for the activities. A matrix showing which activities relate to the various *Scenarios* and ESUs is found following the Framework.

FRAMEWORK FOR EARTH SYSTEMS EDUCATION

UNDERSTANDING #1: Earth is unique, a planet of rare beauty and great value.

- The beauty and value of Earth are expressed by and for people of all cultures through literature and the arts.
- Human appreciation of Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation of Earth through their responsible behavior and stewardship of its subsystems.

UNDERSTANDING #2: Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

- Earth is vulnerable, and its resources are limited and susceptible to overuse or misuse.
- Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- When considering the use of natural resources, humans first need to rethink their lifestyle, then reduce consumption, then reuse and recycle.
- Byproducts of industrialization pollute the air, land, and water; and the effects may be global as well as near the source.
- The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

UNDERSTANDING #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

- Biologists, chemists, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- Direct observation, simple tools, and modern technology are used to create, test, and modify models and theories that represent, explain, and predict changes in the Earth system.
- Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- Scientific study may lead to technological advances.
- Regardless of sophistication, technology cannot be expected to solve all of our problems.
- The use of technology may have benefits as well as unintended side effects.

UNDERSTANDING #4: The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

- The subsystems are continually changing through natural processes and cycles.
- Forces, motions, and energy transformations drive the interactions within and between the subsystems.
- The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- Each component of the Earth system has characteristic properties, structure, and composition, which may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface.
- Weathering, erosion, and deposition continuously reshape the surface of the Earth.
- The presence of life affects the characteristics of other systems.

UNDERSTANDING #5: Earth is more than 4 billion years old, and its subsystems are continually evolving.

- Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up Earth have been recycled many times.
- Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
- Evolution is a theory that explains how life has changed through time.

UNDERSTANDING #6: Earth is a small subsystem of a Solar system within the vast and ancient universe.

- All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
- All bodies in space, including Earth, are influenced by forces acting throughout the solar system and the universe.
- Nine planets, including Earth, revolve around the Sun in nearly circular orbits.
- Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
- The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
- The rotation of Earth on its axis determines day and night.

UNDERSTANDING #7: There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

- Teachers, scientists, and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
- Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
- Scientists from many cultures throughout the world cooperate and collaborate using oral, written, and electronic means of communication.
- Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
- Many people pursue avocations related to planet Earth processes and materials.

The development of this framework started in 1988 with a conference of educators and scientists and culminated in the Program for Leadership in Earth Systems Education. It is intended for use in the development of integrated science curricula. The framework represents the efforts of some 200 teachers and scientists. Support was received from the National Science Foundation, The Ohio State University, and the University of Northern Colorado.

For further information on Earth Systems Education contact the Earth Systems Education Program Office, 2021 Coffey Road, The Ohio State University, Columbus, OH 43210.

Great Lakes Instructional Material for the Changing Earth System (E = Addressed in an extension.)	Earth Systems Understandings							Global Change Scenarios										
	Beauty & Value	Stewardship	Scientific Process	Interactions	Change Through Time	Earth as Subsystem	Careers & Hobbies	Introduction	Water Resources	Biological Diversity	Shipping	Agriculture	Airborne Toxins	Estuaries	Eutrophication	Recreation	Fish Populations	Forest
Activities	1	2	3	4	5	6	7	-	1	2	3	4	5	6	7	8	9	10
The Great Lakes in Perspective - Activity A			X	X					X								X	
The Great Lakes in Perspective - Activity B	X	X						--Varies depending on subject-----------------										
Global Climate Change - Activity A			X	X	X			X										
Global Climate Change - Activity B			X	X				X										
Global Climate Change - Activity C		X	X	X	E	E	E	X										
Global Climate Change - Activity D				X				X										
Great Lakes Climate Factors - Activity A			X	X			X		X									
Great Lakes Climate Factors - Activity B			X	X	X				X									
Visualizing Changes - Activity A				X				X	X	X	X	X	X	X	X	X	X	X
Visualizing Changes - Activity B	X	----------------------------						--Varies depending on subject-----------------										
Visualizing Changes - Activity C	X	----------------------------						--Varies depending on subject-----------------										
Biodiversity / Bird Populations/ CBC			X	X	X					X								
Biodiversity / Forest Ecosystems / Maples	E	E	X	X	X		E											X
Biodiversity / Great Lakes Invaders	E	E	X	X	X	E	E			X							X	
Biodiversity / Great Lakes Fish			X	X	X												X	
Life Support for an Aging Lake - Act. A	X	X	X	X	X										X			
Life Support for an Aging Lake - Act. B				X	X										X			
Estuaries - Places of Diversity - Act. A		X	X	X										X	X			
Estuaries - Places of Diversity - Act. B			X	X	X									X				
Estuaries - Places of Diversity - Act. C			X	X	X									X				
Toxic Chemicals and Global Change - Act A		X	X	E	X		E						X					
Toxic Chemicals and Global Change - Act B		X	X				X						X				X	
Toxic Chemicals and Global Change - Act C			X	X									X				X	
Agriculture and Climate Change			X	X	X		X					X						
Great Lakes Shipping - Activity A			X	X			X				X							
Great Lakes Shipping - Activity B		X	X	X			X				X							
Great Lakes Shipping - Activity C		X	X	X			X				X							
Recreation: Where will we play? - Act. A	X	X		X			X									X		
Recreation: Where will we play? - Act. B	X	X		X			X									X		
Environmental Response - Activity A	----------------------------							--Varies depending on subject-----------------										
Environmental Response - Activity B		X	X				X						X					

National Science Education Standards

The activities in *Great Lakes Instructional Materials for the Changing Earth System (GLIMCES)* have connections to other national developments in science education. Numerous efforts have been underway in the 1990s to restructure science education in response to growing concerns that the historic "layer cake" (discipline-ordered) approach to science lacks relevance to students, prepares them poorly in life skills that demand science literacy, leaves U.S. students lagging on standardized international tests of science knowledge, and ignores or perhaps even perpetuates naive conceptions in science. The primary efforts to change these patterns have emerged from and been supported by national organizations in science and education.

The National Science Education Standards represent the National Academy of Science's attempt to develop guidelines for science curriculum restructure and systemic change in K-12 education. The National Standards include science content standards that express need for integration of disciplines, fewer topics in greater depth, and articulation across grade levels. They do more by providing guidelines for restructuring the teaching of science, the environment for science in schools, and assessment of science learning. The Standards emerged in 1995 as the most comprehensive and perhaps most esteemed of the restructure guidelines.

The following matrix demonstrates the connections of GLIMCES activities to many of the National Science Education Standards.

CONTENT STANDARDS, GRADES 5-8

Science as inquiry
- Abilities related to scientific inquiry
- Understanding about scientific inquiry

Physical science
- Properties and changes of properties in matter
- Motions and forces
- Transformations of energy

Life science
- Populations and ecosystems
- Diversity and adaptations of organisms

Earth and space science
- Structure of the Earth system
- Earth's history

Science and technology
- Understanding about science and technology

Science in personal and social perspectives
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

History and nature of science
- Science as a human endeavor
- Nature of science

Unifying concepts and processes
- Order and organization
- Evidence, models, and explanation
- Change, constancy and measurement
- Evolution and equilibrium
- Form and function

Content standards, Grades 9-12

Science as inquiry
- Abilities related to scientific inquiry
- Understanding about scientific inquiry

Physical science
- Chemical reactions
- Forces and motions
- Conservation of energy
- Interactions of energy and matter

Life science
- Biological evolution
- The interdependence of organisms

Earth and space science
- Energy in the Earth system
- Origin and evolution of the Earth system

Science and technology
- Understanding about science and technology

Science in personal and social perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and nature of science
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Unifying concepts and processes
- Order and organization
- Evidence, models, and explanation
- Change, constancy and measurement
- Evolution and equilibrium
- Form and function

Great Lakes Instructional Materials for the Changing Earth System ***address a large number of the National Science Education Standards***

Benchmarks for Science Literacy

"Students should have opportunities to reflect on the value of thinking in terms of systems and to apply the concept in diverse situations."

–*Project 2061, 1993*

Project 2061 is supported by the American Association for the Advancement of Science (AAAS). Through its book *Science for All Americans*, this project identified science concepts that every high school graduate in the United States should know. Major contributions of this effort include the idea that "less is more," or that a curriculum dealing with fewer concepts in greater detail is preferred over the traditional vocabulary-laden mini-college courses common in U.S. secondary schools. Follow-up work through selected school districts produced several models for implementing the curriculum changes implied by 2061, and has resulted in a set of Benchmarks for designing the course sequences and gauging the progress of students in science through their school careers.

Many of the Benchmarks are addressed through activities in this volume. They are too numerous to list here in their entirety, but the following Benchmarks are among those applicable to the activities.

Common Themes: Systems

By the end of the 8th grade, students should know that

- A system can include processes as well as things.
- Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole.
- Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem of a larger system.

By the end of the 12th grade, students should know that

- Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis. In defining a system, it is important to specify its boundaries and subsystems, indicate its relation to other systems, and identify what its input and its output are expected to be.
- Even in some very simple systems, it may not always be possible to predict accurately the results of changing some part or connection.

Habits of Mind: Critical-Response Skills

By the end of the 8th grade, students should

- Be aware that there may be more than one good way to interpret a given set of findings.
- Notice and criticize the reasoning in arguments.

By the end of the 12th grade, students should

- Insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position. can be judged.
- Be aware that when people try to prove a point they may select only the data that support it and ignore any that would contradict it.
- Suggest alternative ways of explaining data and criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration. Suggest alternative trade-offs in decisions and designs.

Additional Connections for Global Change Education

Like the educational technologies we use in classrooms, this list will never be complete or current. It does contain some useful materials as starting places for additional information about global change in general and the Great Lakes in particular.

NOAA Global Change Education Program
NOAA, U.S. Department of Commerce
1100 Wayne Ave., Rm. 1210, Silver Spring, MD 20910-5603
Phone: 301/427-2089
HomePage: http://www.noaa.gov

U.S. Global Change Research Program
Publishes an annual agenda and update for research on global change, for example, the report titled *Our Changing Planet: The FY 1995 U.S. Global Change Research Program.*
Coordination Office of the U.S. Global Change Research Program
300 D Street, SW, Suite 840, Washington, D.C. 20024
E-Mail: office@usgcrp.gov
HomePage: http://gcrio.gcrio.org/

Great Lakes Environmental Research Laboratory (GLERL)
GLERL has been assigned the responsibility of "developing the U.S. component of a binational Great Lakes global climate change study" (Great Lakes Climate Change Project, 1994).
Great Lakes Environmental Research Laboratory
2205 Commonwealth Blvd., Ann Arbor, MI 48105
Phone: 313/741-2235
E-Mail: all-glerl@glerl.noaa.gov
HomePage: http://www.glerl.noaa.gov/

Canadian Atmospheric Environment Service
Environment Canada
4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4

International Joint Commission (IJC)
The IJC published *1993-95 Priorities and Progress under the Great Lakes Water Quality Agreement.* Under the Priorities Summary, the IJC identifies the importance of understanding global climate change.

International Joint Commission home office
100 Ouellette Avenue, Windsor, ON N9A 6T3
Phone: 519/256-7821

International Joint Commission Detroit Office
P.O. Box 32869, Detroit, MI 48232
Phone: 313/226-2170

HomePage: http://gopher.great-lakes.net:2200/1m/partners/IJC/dglem/dglem.txt (Great Lakes educational)

"The goal of the Binational Implementation Plan is to undertake research which will improve the understanding of the complex interaction between climate change and variability, the environment, and our social and economic systems so that informed regional adaptation responses can be developed for the sustainable management of the region." The IJC identifies areas for continued research on:

". . . impact of climate variability and change on groundwater, ecosystem processes, wetlands, biodiversity, lake circulation and water quality
impact of changing agroclimatic conditions on agricultural practices
impact of climate change on long-range transport and atmospheric loadings of toxics."

The IJC Science Advisory Board recommends that every five years a "symposium on climate change in the Great Lakes Basin be sponsored . . . . as an important scientific forum for discussion and to measure progress towards climate change assessment and adaptation" (1993-95 Priorities, 1995).

Great Lakes Commission
This is an interstate commission of the eight Great Lakes states.
Great Lakes Commission
The Argus II Building, 400 Fourth St., Ann Arbor, MI 48103
Phone: 313/665-9135

Global Learning and Observations to Benefit the Environment (GLOBE)
GLOBE
742 Jackson Place, Washington, DC 20503
Phone: 202/395-7600.
HomePage: http://www.globe.gov

Intergovernmental Panel on Climate Change (IPCC)
The IPCC was formed "in 1988 as a technical body for the scientific assessment of climate change and its first assessment report was completed in 1990." The panel gave "1990 estimates of future warming of about 0.3°/ decade." Its responsibility has been acquired by the U.S. Global Change Research Program. The Working Group II is co-chaired by the U.S.
HomePage: http://www.usgp.gov/ipcc/

Wisconsin Sea Grant, Global Change Education Program
Maintains a list of trained global change educators in the region, and an electronic mailing list for updates of information and opportunities. Provides regional workshops for educators and participant materials. The funding is generated from the Office of Global Programs, NOAA.
HomePages: http://h2o.seagrant.wisc.edu/home.html
http://h2o.seagrant.wisc.edu/uwsg/directry/related4.html

Cooperative Institute for Limnology and Ecosystems Research (CILER)
Its research focuses on climate and large-lake dynamics, coastal and near shore processes, and large lake ecosystem structure and function. This and other information can be found on the WorldWideWeb.
http://www.glerl.noaa.gov/ciler/ciler.html
It comprises University of Michigan, Michigan State University and GLERL
CILER
University of Michigan, Ann Arbor, MI 48109

Carbon Dioxide Information Analysis Center
Excellent continuously up-to-date source of data on greenhouse gases.
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6335
Phone: 615/574-0390

Internet sites of general interest
National Climatic Data Center: http://www.ncdc.noaa.gov
U.S. Army Corps of Engineers, Detroit District: http://sparky.nce.usace.army.mil
Great Lakes Forecasting System: http://glfs.eng.ohio-state.edu

Publications and other Materials

National Informal Educators Conference on Global Change (Videotape)
Sponsored by NOAA, Office of Global Programs, the Sea Grant College Program, and Project Earthlink. Hosted by Lynne M. Carter, Director, Marine Education Programs, Graduate School of Oceanography, University of Rhode Island. This video is based on a teleconference for global change education, November 1994, and may be duplicated for educational purposes.

Activities for the Changing Earth System (ACES)
Earth Systems Education Program, c/o Rosanne Fortner
The Ohio State University School of Natural Resources, 2021 Coffey Rd., Columbus, OH 43210
Phone: 614/292-9826
E-Mail: rfortner@magnus.acs.ohio-state.edu

Global Climates – Past, Present, and Future
EPA. June 1993. Activities for Integrated Science Education. Edited by Sandra Henderson, Steven R. Holman, and Lynn L. Mortensen.
EPA/600/R-93/126

The Great Lakes Charter, 1985
Council of Great Lakes Governors
35 East Wacker Drive, Suite 1850, Chicago, IL 60601

Great Lakes Climate Change Report
Research Priorities for Assessing the Impacts of Climate Change in the Great Lakes Basin. March 1994. Proceedings of the Great Lakes Climate Change Workshop, December 6-8, 1993. Edited by Clare M. Ryan, Frank H. Quinn, and Michael J. Donahue. Ypsilanti, MI.
Sponsored by NOAA, CILER and Great Lakes Commission

The Great Lakes Forecasting System, Department of Civil Engineering, The Ohio State University, with support from GLERL, NOAA. This on-line system makes predictions of physical variables of the Great Lakes and gives maps of existing conditions updated every six hours.
HomePage: http://glfs.eng.ohio-state.edu/

Martin, Thomas D., and Jan J. Hacker. Autumn 1985. "The Great Lakes Charter: Blueprint for Regional Cooperation." *Renewable Resources Journal.* vol. 3, no. 4, pp. 4, 20-21.

Mayer, V. J. and R. W. Fortner, 1995. *Science is a Study of Earth: A resource guide for science curriculum restructure.* Columbus, OH: Earth Systems Education Program, The Ohio State University.

Quotes included with organizations are taken from *1993-95 Priorities and Progress under the Great Lakes Water Quality Agreement.* August 1995. Canada: International Joint Commission.

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Great Lakes in Perspective

Activity A: How well do you know the Great Lakes?

Many people, including a large proportion of those who live close to the Great Lakes, do not have a basic understanding of the individual characteristics of and the differences between the lakes. Since it is difficult to understand many of the Great Lakes issues such as global warming, pollution, and water use without a basic understanding of the lakes, this activity is designed to help visualize the differences in the volume, length of shoreline, human population distribution, and fish populations of the Great Lakes. These categories are visually represented so that students can put the lakes in perspective with each other. This activity could be used as an introductory activity to the study of other Great Lakes issues.

Objectives

In this activity, students will develop a perception of the differences between the Great Lakes regarding their water volumes, length of shoreline, human population distribution, and the amount of fish harvested from each lake.

Procedure

1. In this activity the students will work in groups. Each student should be assigned to a base group and an expert group.

   Expert Groups

   There should be a total of five expert groups, one assigned to each lake. Each expert group studies one lake and members become "experts" on that lake.

   Base Groups

   The base groups should have five (or more) people in them; in this group students from the different expert groups come together to share their knowledge. There must be at least one member from each expert group (in other words, a representative from each lake) in each base group so that every lake has a spokesperson.
2. After group assignments have been made, the students begin by gathering in their base groups. These groups should each be situated around a cluster of desks or in an open area. The base groups then make their best guess about the following characteristics of the Great Lakes:

   Shoreline

   Give each group one of the prepared sets of five strings (See *Using the Data* Step 1). The groups should try to

Earth System Understandings

This activity relates to #3 (science methods and technology) and #4 (interactions). Refer to the introduction of this book for a full description.

Materials

Each base group (of five students) will need:
- A set of five labeled strings as described in step one of *Using the Data*
- 100 squares of blue paper
- One sheet of paper cut into five strips (1 strip for each lake)
- Twenty "fish" (they could be washers, corn kernels, or peanuts...)
- A pen or pencil

Each of the five expert groups will need:
- Access to a map of the Great Lakes
- A copy of the *Great Lakes Data* (other resource books are optional)

Teacher's Note

An easy way to divide the students into base groups and expert groups may be to divide them into groups of five students (base groups) and have each member of those groups choose a lake (which hasn't already been chosen by a member of their group), thus creating the expert groups.

arrange their labeled strings to form a model of the outline of the Great Lakes (without referring to an actual map).

Water volume

Have each group of students distribute their 100 squares of blue paper among the lakes. The 100 squares together represent all of the water contained in the lakes. If a group thinks that the water is divided equally among the lakes, then they would put 20 blue squares into each lake.

Human population

Have each group cut five strips of paper which will be placed along the shoreline of the lakes (one for each lake). Tell the students the total population of people living in the Great Lakes watershed (31.7 million). The students should then divide that number between the Great Lakes. For instance, if they think that about half of the people in the Great Lakes watershed live on Lake Superior then they would write 16 million on a strip of paper and place it next to the Lake Superior coastline. The goal is not for the students to get the number correct but for them start thinking about where people are located around the lakes. Instead of writing actual numbers on the strips of paper, the lakes could be ranked from 1-5 for most population to least population.

Fish

Try to predict the amount of fish taken from each lake for human food. Give each group 20 "fish." These 20 fish represent all of the fish taken out of the Great Lakes. If the students think, for instance, that almost all of the total fish come from Lake Superior, then they should put 18 or 19 fish in that lake.

3. After the base groups have made their guesses, the students move into their expert groups. These five groups, each assigned to one of the lakes, look at all the data available on their lake so that when the students move back to their base groups they will be able to correct the guesses that their base group made. You may either give them the correct percentages or have the students figure them out.
4. Students return to base groups to correct their models and discuss the review questions.

Review Questions

1. What was the most surprising thing about this activity? Discuss why.
2. Which guesses were not close to the correct answers? What reasoning led the group to its wrong decisions?
3. Why do the majority of the people live around Lake Erie?
4. Why don't the length of coastline and the amount of water correspond?
5. How did the groups work out differences of opinion in order to come to common agreement?

Answers

1. Students may find the amount of fish gathered and the amount of people living on Lake Erie surprising because of the lake's relatively small size.
2. Answers will vary.
3. There are several reasons, one is that Lake Erie produces more fish for human consumption than all the other lakes combined. Also, its climate is warmer.
4. The depths of the lakes are very different.
5. Answers will vary.

EXTENSIONS

1. As a class or individually, pick a question pertaining to the Great Lakes (for instance: "Which lake on a map of the Great Lakes is Lake Huron?" or "Which of the Great Lakes has the largest human population living in its watershed?") and have the students ask the question to a variety of people either around the school or in their communities. This may lead to interesting discussions concerning the possibility that the voting public may make uninformed decisions.

2. Each group of students could try to find an additional set of data about the Great Lakes such as average depth, fish populations, average water retention time, level of pollution, etc. to present to the class or to lead the class through, as with the other data sets.

USING THE DATA

These notes should help with interpreting the *Great Lakes Data* chart and with setting up the experiment.

Shoreline

In order to make strings that depict the relative lengths of shoreline of the Great Lakes, use the relative length data in the shoreline section. Any unit of measurement may be used as long as it is used consistently. The measurement units will depend on the amount of space available for the lesson. For instance, if the lesson will be taught outdoors, a large unit of measurement may be used such as meters. In this case the Lake Superior string would be 3.0 meters long. Make sure each string is labeled with a piece of tape.

Water volume

The student groups each have 100 blue squares that represent all of water in the Great Lakes combined. To find how 100 squares should be distributed, look at the relative volume section in the volume category. It lists 54 for lake Superior. This means that 54 of the squares should be in the Lake Superior string model (over half of the water is in Lake Superior).

Human population

The total population data figures are rounded off in the section Population to the nearest 0.5 million. The students attempt to guess the numbers in this category. It is interesting to realize that Lake Superior has only 0.5 million people living near it. This is less than 2 percent of the total population of the Great Lakes watershed.

Fish

The row labeled *"amount of fish if the total number was 20"* of the chart indicates the number of pounds of fish that would come from each lake if the total number of pounds from all the lakes was 20. Each base group of students should be given (or make) 20 "fish" so that they can make their best guess as to how the fish should be distributed in their string bordered "lakes."

Great Lakes Data

		Superior	Michigan	Huron	Erie	Ontario	Total
Shoreline (with Islands)	Miles	2,980	1,659	3,827	871	726	10,063
	Relative length	3.0	1.6	3.8	.9	.7	10.0
Water Volume [a]	cu. miles	2,900	1,180	850	116	393	5,439
	km³	12,100	4,920	3,540	484	1,640	22,684
	Relative volume	54	22	15	2	7	100
Human Population in Watershed	U.S. & Canada (1991)	500,000	8,500,000	2,700,000	12,000,000	8,000,000	31,700,000
	Population to nearest 1,000,000	.5	8.5	2.7	12	8	31.7
Annual Commercial Fishing Harvest	U.S. (lbs)	2,877,240	44,000,000	4,747,267	5,793,590	232,551	57,650,648
	Canada (lbs)	1,648,681		6,378,861	40,620,666	1,212,728	49,860,936
	Totals:	4,525,921	44,000,000	11,126,128	46,414,256	1,445,279	107,511,584
	Amount of fish harvested if the total number was 20	1	8	2	9	0	20
	Number of fish species	45	78	87	100	90	

[a] Measured at Low Water Datum

REFERENCES

Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. Coordinated Great Lakes Physical Data. May, 1977.

Extension Bulletins E-1866-70, Michigan Sea Grant College Program. Cooperative Extension Service, Michigan State Univ. E. Lansing, MI. 1985.

The Life of the Lakes, Michigan Sea Grant and Michigan State University (1991 Data).

Activity B: How great *are* the Great Lakes?

When we consider the VALUE of something, we put a price, literally or figuratively, on its importance to us. Certain things have a measurable value, like the price of fish fillets or the cost of a bag of salt mined from under the lakes. Those people who don't like fish or who don't use salt will naturally place a low value on these items and will avoid their purchase. On the other hand, they may enjoy sailing and invest large amounts of money in a boat and dockage fees. Value is a personal judgment.

Some commodities have an artificially applied value based on perceived importance. For instance, lakefront hotel rooms often cost more per night than identical rooms facing inland. Fast, flashy cars cost more than economy cars equally capable of transporting people from place to place.

Still other things have no price tags at all but clearly have value to some people: a quiet place to walk on the beach, a golden sunset, the sight of an eagle overhead. A glass of pure drinking water is a thing of great value in most of the world. In most parts of North America we take drinking water for granted.

Procedure

1. Have students individually brainstorm as complete a list as possible of valuable aspects of the Great Lakes. Bring the individual lists to the class and compile a composite list for all to see.

2. Did the students consider personal, industrial, lifestyle, and aesthetic values as well as things that can be bought because of the lakes? Discuss.

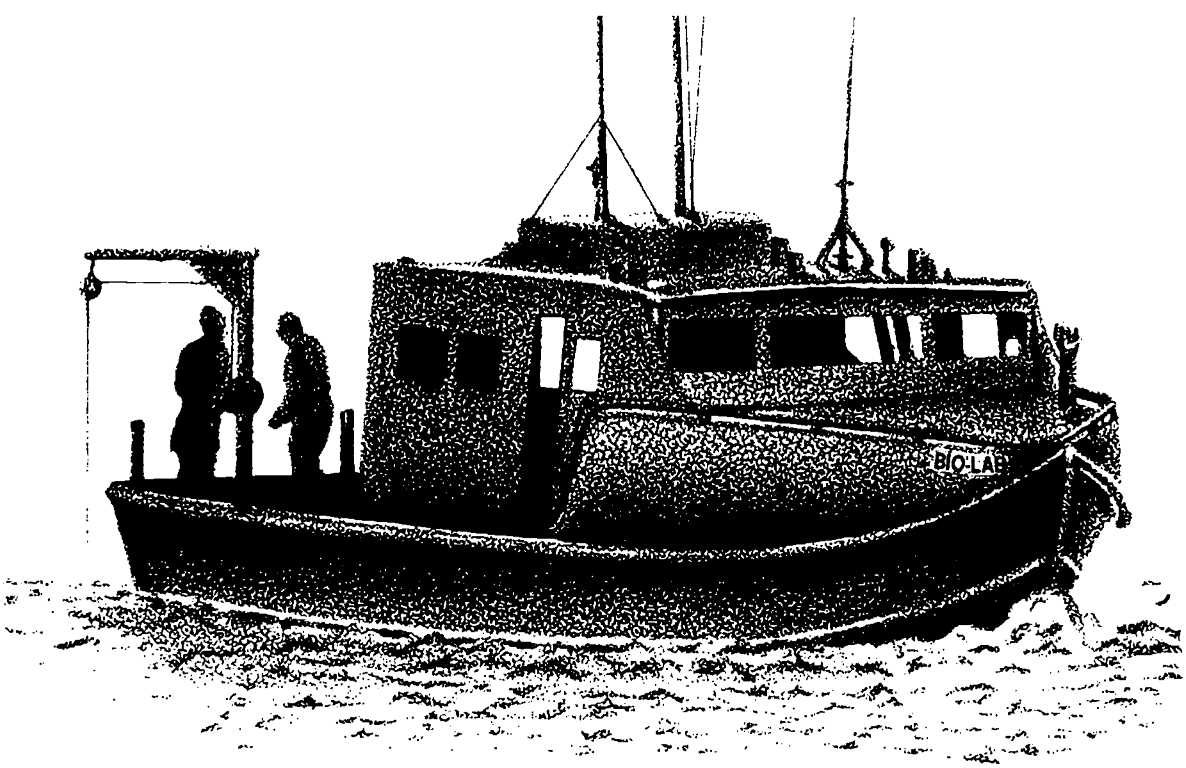
3. For each valuable thing on the list, have the students tell how the value is measured and by whom. Do any students NOT see value in some of the things on the list? Discuss.

4. In small groups and then with the class, have students select the *Desirable Dozen*; those 12 things they consider most valuable about the Great Lakes. Discuss differences in the choices, but allow all possibilities to be accepted.

FOLLOW-UP

This activity tends to generate deep thought and personal searching. In a portfolio entry or essay, encourage individual students to explore their own set of values and how they would make trade–offs to keep those things they consider most valuable.

Share your classes' list of values with other students in the region. Send it to the Great Lakes Information Network to be shared on the Education Bulletin Board! Mail to GLIN Systems Operator, CICnet, 2901 Hubbard Ave., Ann Arbor, MI 48105, or send electronic mail to glin.education@great-lakes.net, and all the readers of the bulletin board will share it.



Global Climate Change

Over the past 20 years, much attention has been focused on the potential climatic effects of rising levels of atmospheric greenhouse gases, such as carbon dioxide, methane, and CFCs. Human activities as well as natural factors increase the levels of these gases in the atmosphere. A great deal of research has been done during the past two decades regarding the potential global significance of the increased greenhouse gas concentrations. In addition to receiving attention by the scientific community, global temperature fluctuations and other notable climate variations are causing a great deal of concern for average citizens worldwide. Advances in computer and communication technologies have allowed people to access and share large amounts of global climate information. The media have been an important part of this communications revolution, keeping the public informed on environmental issues. The information that we receive, however, can be conflicting and confusing.

Against a backdrop of controversy, government policy makers must decide whether or not to take action to reduce greenhouse gas emissions. Some policy makers argue that scientists do not agree on the problem, and therefore, they oppose any specific timetables for combating global warming. Others call for the establishment of specific targets to cut the production of human made greenhouse gases, principally carbon dioxide and methane.

A key to understanding the global warming debate is to understand how predictions are made. By recognizing the strengths and weaknesses of predictions based on one data record, for instance, in observing temperature trends, the debate over global warming can become easier to understand.

Earth Systems Understandings

This activity focuses primarily on ESUs #3 (science methods and technology), #4 (interactions), and #5 (change through time). Refer to the introduction of this book for a full description of the understandings.

Scenario Reference

Introduction: Understanding climate models.

Materials

- Global and the Great Lakes region temperature data sets provided
- Graph scale provided
- Colored pencils
- Masking tape

Activity A: Is the globe warming? Is there evidence in the Great Lakes region?

Objectives

After completing this activity, students will be able to:
- Critically interpret graphic data.
- Evaluate and discuss the difficulties inherent in interpreting and forecasting long- and short-term trends.
- Analyze data, draw conclusions about whether there is evidence of global warming, and defend their conclusions.

Procedure

In preparation, cut apart the sections of the Global Temperature and Great Lakes Temperature lists (p. 9 and p.12) so each group will see only one segment of each. Make a copy of the graph scale for each team to graph its data.

1. Have students read Ohio Sea Grant's *Global Change Scenarios* "Introduction: Understanding Climate Models."
2. Divide the class into five groups that will work separately. Each group will receive a copy of one global temperature data set (28 years) and colored pencils. Students should graph their set of data on the scale provided. As they observe how readings fluctuate from year to year, students can theorize whether there is any evidence that the global temperature was rising, falling, or remaining constant during the period they are studying. They should be able to back up their conclusions with data from their sample graphs.
3. The students then project what the graph of global surface air temperature will be 30 years into the future (from the last year of their graph), based on the trends and periodicities they observe in their individual data set. This should be drawn on the right side of the graph in a different color.
4. Repeat the exercise (Steps 2–3) using temperature data from the Great Lakes. Plot the data on the same graph sheets used for the global data, but this time using new colors so that four different colors appear on the graph. Have the class agree to use similar colors. How do Great Lakes temperature variations compare with those of the whole world? Did they always show parallel trends? How does the complete regional graph compare to the global graph?

(PROCEDURE *continues on page 14.)*

Teacher's Notes

Graphing Ideas
Students can plot increments of 0.1 degree on the Y axis and years on the X axis. The last point of their actual data should be on the line that divides the right side of the graph from the left "projection" side. The actual graphs are found on subsequent pages set aside for the teacher's use. Students typically project steep increases from their small data sets.

Basis of Data
Global temperature anomaly data are based on Jones and Wigley's work using both land and marine data. Researchers have compiled global average surface air temperature data from land–stations, a few fixed–position weather ships, and many moving ships. Temperature Anomalies are listed relative to a 1950-1979 reference period for Global and a 1961-1990 reference period for Great Lakes Data. *Anomalies* are variations from average values.

Limitations of Data
Students should discuss the limitations of the data set. If measurements were more heavily weighted on land data, that might contribute to greater extremes than if they were collected over water. Also, the data from ships leave many large data gaps over the oceans. There may be no way to tell just by looking at the data what limitations exist. To become good consumers of scientific information, students must consider the limitations of any data set.

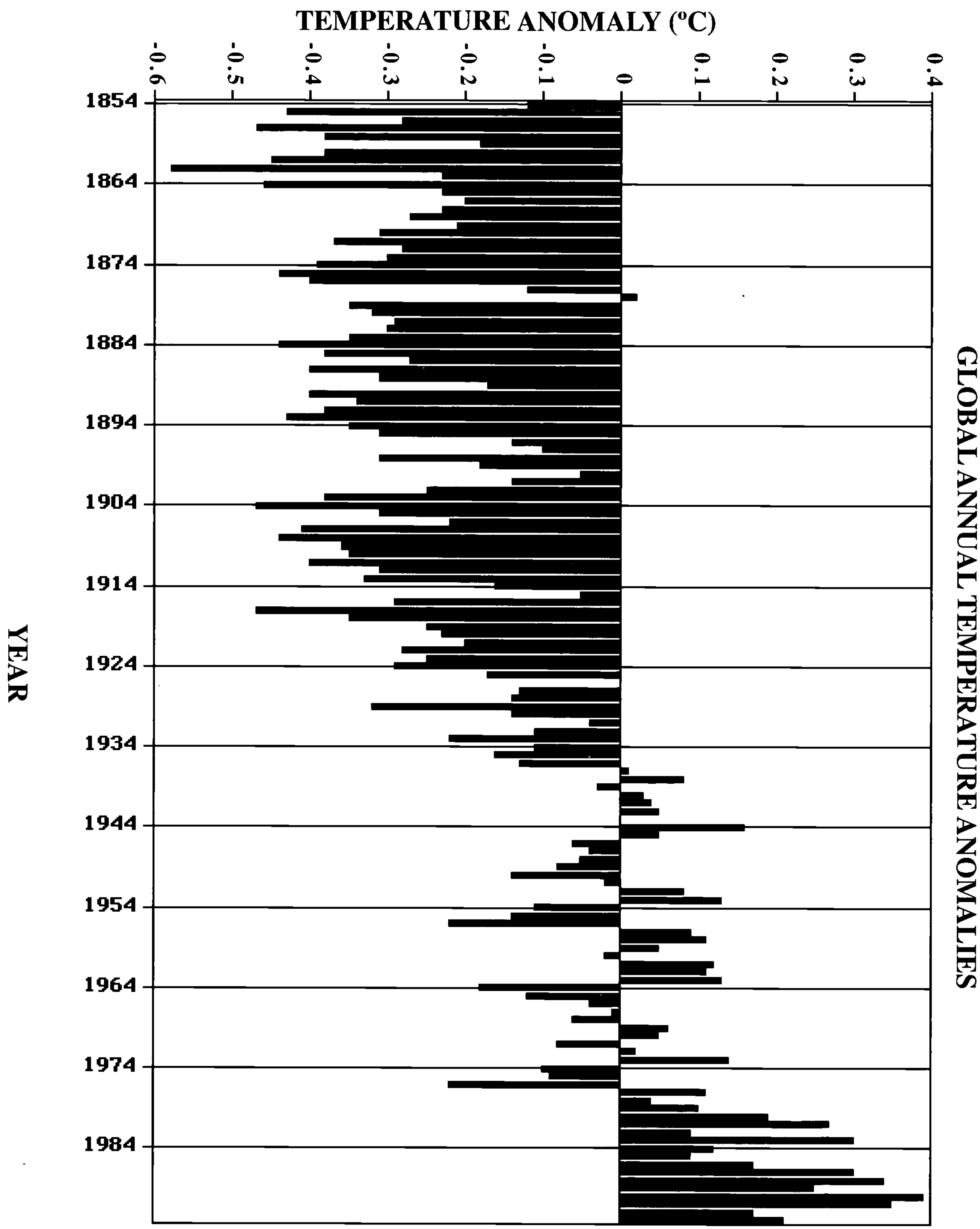
GLOBAL ANNUAL TEMPERATURE ANOMALY DATA (C°)

Year	Temperature Anomaly	Year	Temperature Anomaly	Year	Temperature Anomaly
1854	-0.12	1882	-0.30	1910	-0.35
1855	-0.43	1883	-0.35	1911	-0.40
1856	-0.28	1884	-0.44	1912	-0.31
1857	-0.47	1885	-0.38	1913	-0.33
1858	-0.38	1886	-0.27	1914	-0.16
1859	-0.18	1887	-0.40	1915	-0.05
1860	-0.38	1888	-0.31	1916	-0.29
1861	-0.45	1889	-0.17	1917	-0.47
1862	-0.58	1890	-0.40	1918	-0.35
1863	-0.23	1891	-0.34	1919	-0.25
1864	-0.46	1892	-0.38	1920	-0.23
1865	-0.23	1893	-0.43	1921	-0.20
1866	-0.20	1894	-0.35	1922	-0.28
1867	-0.23	1895	-0.31	1923	-0.25
1868	-0.27	1896	-0.14	1924	-0.29
1869	-0.21	1897	-0.10	1925	-0.17
1870	-0.31	1898	-0.31	1926	0.00
1871	-0.37	1899	-0.18	1927	-0.13
1872	-0.28	1900	-0.05	1928	-0.14
1873	-0.30	1901	-0.14	1929	-0.32
1874	-0.39	1902	-0.25	1930	-0.14
1875	-0.44	1903	-0.38	1931	-0.04
1876	-0.40	1904	-0.47	1932	-0.11
1877	-0.12	1905	-0.31	1933	-0.22
1878	0.02	1906	-0.22	1934	-0.11
1879	-0.35	1907	-0.41	1935	-0.16
1880	-0.32	1908	-0.44	1936	-0.13
1881	-0.29	1909	-0.36	1937	0.01
1938	0.08	1966	-0.04		
1939	-0.03	1967	-0.01		
1940	0.03	1968	-0.06		
1941	0.04	1969	0.06		
1942	0.05	1970	0.05		
1943	0.00	1971	-0.08		
1944	0.16	1972	0.02		
1945	0.05	1973	0.14		
1946	-0.06	1974	-0.10		
1947	-0.04	1975	-0.09		
1948	-0.05	1976	-0.22		
1949	-0.08	1977	0.11		
1950	-0.14	1978	0.04		
1951	-0.02	1979	0.10		
1952	0.08	1980	0.19		
1953	0.13	1981	0.27		
1954	-0.11	1982	0.09		
1955	-0.14	1983	0.30		
1956	-0.22	1984	0.12		
1957	0.09	1985	0.09		
1958	0.11	1986	0.17		
1959	0.05	1987	0.30		
1960	-0.02	1988	0.34		
1961	0.12	1989	0.25		
1962	0.11	1990	0.39		
1963	0.13	1991	0.35		
1964	-0.18	1992	0.17		
1965	-0.12	1993	0.21		

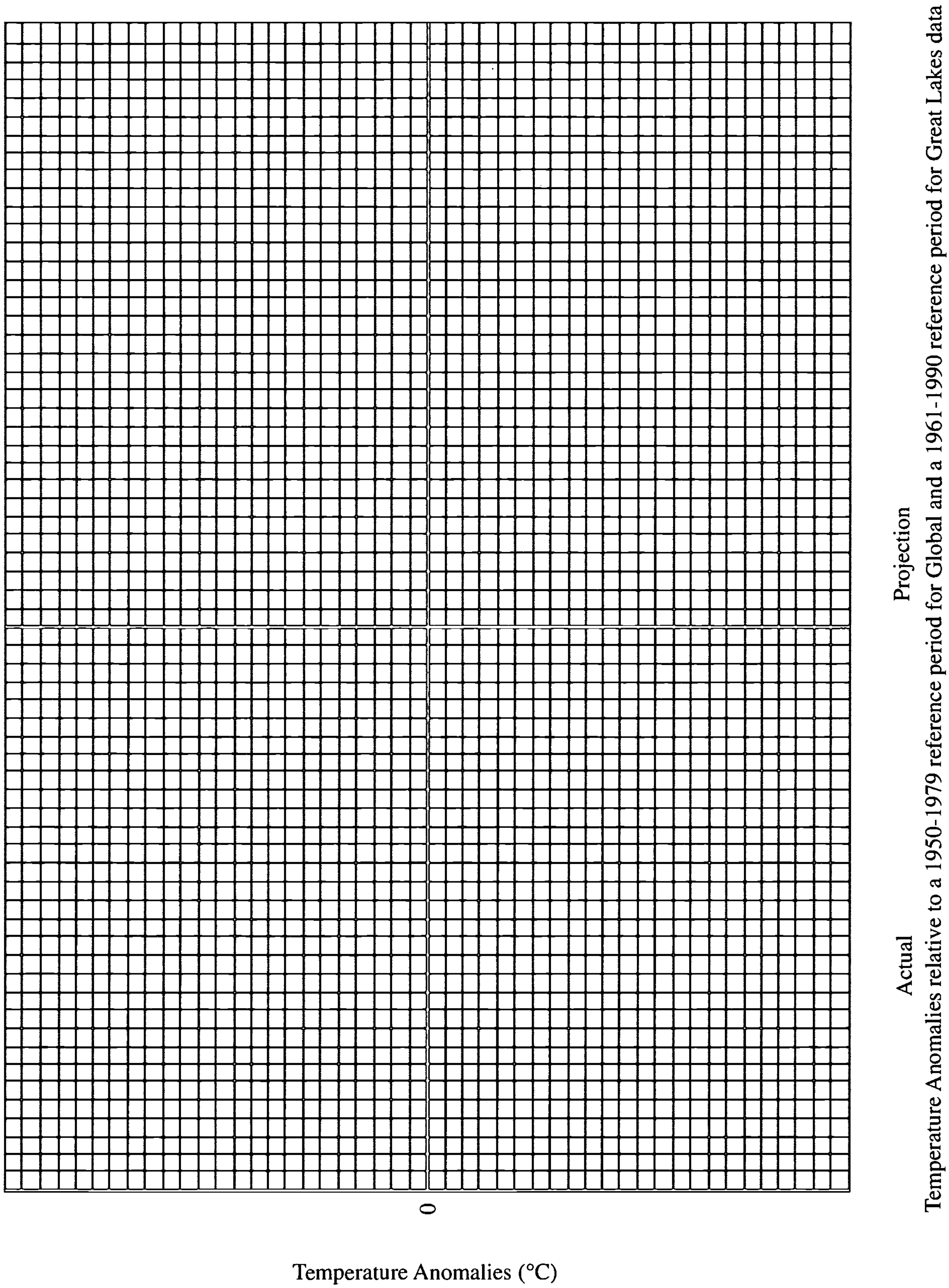
To The Teacher: Give one set of data to each group of students.

Jones, P.D., T.M.L. Wigley and K.R. Briffa. 1994. Global and hemispheric temperature anomalies – land and marine instrumental records. In, T.A. Boden, D.P. Kaiser, R.J. Sepanski and F.W. Stoss (eds.), *Trends '93: A Compendium of Data on Global Change.* ORNL/CDIAC-65. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN. pp. 603-608.

Teacher's Page: Graph of Global Annual Temperature Anomaly Data



Graph for Global and Great Lakes Temperature Activity



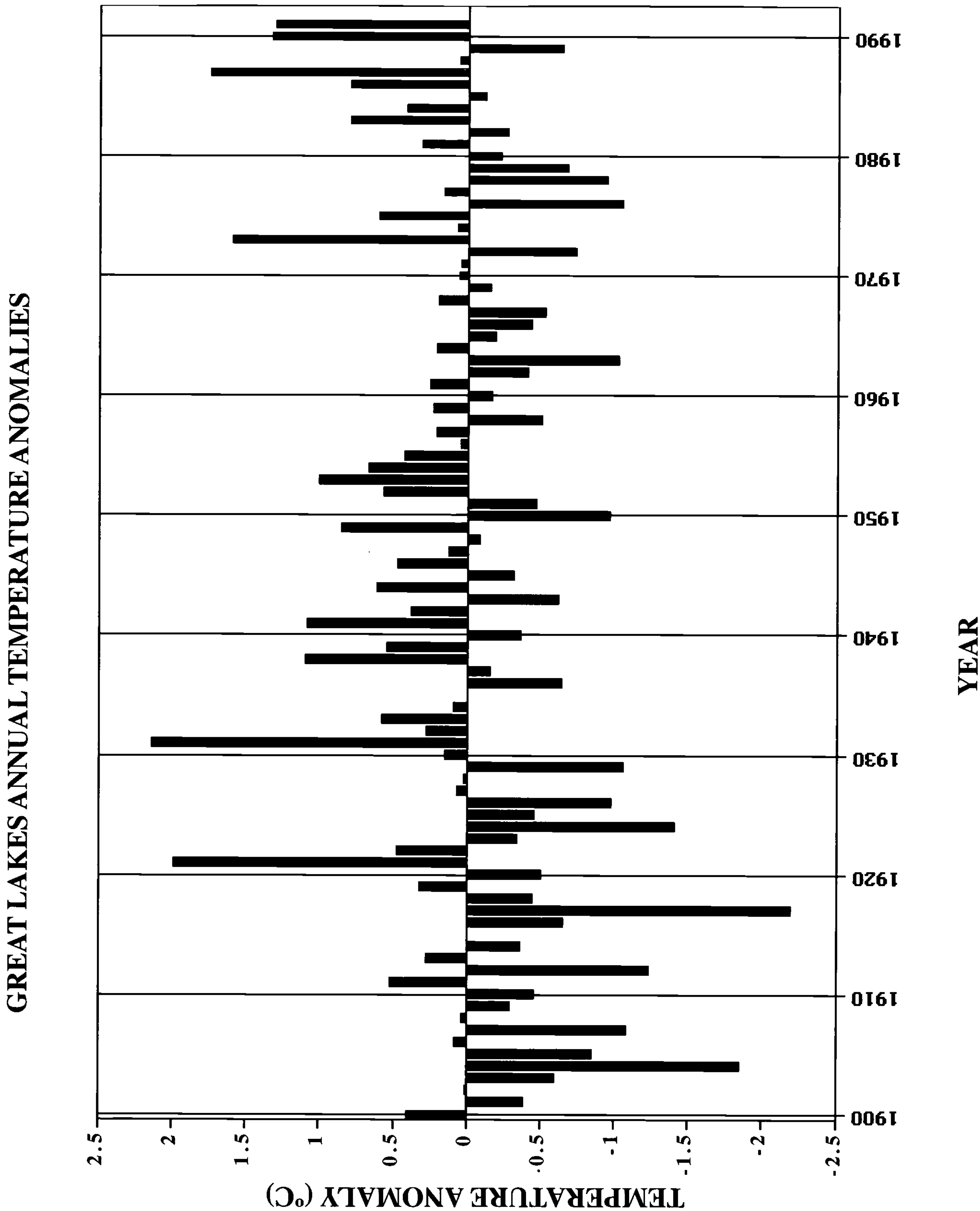
GREAT LAKES ANNUAL MEAN TEMPERATURE ANOMALY DATA (°C)

Year	Mean Temperature Anomaly	Year	Mean Temperature Anomaly	Year	Mean Temperature Anomaly
1900	0.40	1919	0.32	1938	1.10
1901	-0.39	1920	-0.50	1939	0.54
1902	0.01	1921	1.99	1940	-0.36
1903	-0.59	1922	0.47	1941	1.08
1904	-1.85	1923	-0.34	1942	0.38
1905	-0.85	1924	-1.41	1943	-0.62
1906	0.08	1925	-0.46	1944	0.61
1907	-1.08	1926	-0.98	1945	-0.32
1908	0.03	1927	0.07	1946	0.47
1909	-0.29	1928	0.02	1947	0.12
1910	-0.45	1929	-1.06	1948	-0.09
1911	0.52	1930	0.15	1949	0.85
1912	-1.23	1931	2.14	1950	-0.96
1913	0.28	1932	0.28	1951	-0.47
1914	-0.36	1933	0.58	1952	0.56
1915	0.00	1934	0.09	1953	1.00
1916	-0.65	1935	0.00	1954	0.67
1917	-2.19	1936	-0.64	1955	0.42
1918	-0.44	1937	-0.15	1956	0.04
1957	0.21	1975	0.60		
1958	-0.50	1976	-1.05		
1959	0.23	1977	0.16		
1960	-0.16	1978	-0.94		
1961	0.25	1979	-0.67		
1962	-0.41	1980	-0.22		
1963	-1.02	1981	0.31		
1964	0.20	1982	-0.27		
1965	-0.19	1983	0.79		
1966	-0.43	1984	0.41		
1967	-0.52	1985	-0.12		
1968	0.19	1986	0.79		
1969	-0.15	1987	1.75		
1970	0.06	1988	0.06		
1971	0.04	1989	-0.64		
1972	-0.73	1990	1.33		
1973	1.59	1991	1.30		
1974	0.07				

To The Teacher:
Give one set of data to each group of students.

Karl, T.R., D.R. Easterling, R.W. Knight and P.Y. Hughes. 1994. U.S. national and regional temperature anomalies. In, T.A. Boden, D.P. Kaiser, R.J. Sepanski and F.W. Stoss (eds.), *Trends '93: A Compendium of Data on Global Change.* ORNL/CDIAC-65. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN. pp. 686-736.

Teacher's Page: Graph of Great Lakes Mean Temperature Anomaly Data



If the graphs of the same years are compared on different scales, it appears that variations in Great Lakes temperatures were large in comparison to global temperatures. Why are there more extremes in the Great Lakes data set? Global temperatures are a combination of values across the earth. Extremes are averaged out. Large variations are not as visible as they are in a regional data set like that of the Great Lakes. Regional data will often show a larger range of highs and lows because these extremes aren't "hidden" as well by averaging.

Answers to Questions

1. a. The more data, the more certain we can be about trends. In this case, centuries of data are needed.
   b. No, data collection methods have varied over the years.
   c. They are the only information we have, and something is better than nothing. They do need to be used with caution, however.
   d. Accept many answers — human error, instrument failure, and effects of cities, cars, and industries, which can generate heat and may affect the surrounding climate.

2. Answers will vary based on class projections.

3. Answers will vary based on readings and student knowledge, but should include things like vegetation effects, arctic permafrost effects, ocean circulation, greenhouse gases, cloud effects, etc.

5. Each group, beginning with the first (1854-1881) temperature chart, should present their data, along with predictions for average global and Great Lakes temperatures 30 years in the future. Compile the graphs of each group into a single graph to show the class. The first group hangs its graph on the front wall. The next group then covers the previous group's predictions with the actual data. Some teachers create a data timeline along the classroom wall or in a hallway. Students can compare their estimates with the actual data.

Questions for Discussion

1. Groups should consider their predictions and answer the following:
   a. How much data do we need to plot a trend?
   b. Were weather collection methods the same for all data sets being reviewed? (e.g., how were weather data collected in 1885?)
   c. Even if the data are old, do they have value?
   d. Besides measurement techniques, what other factors may influence the reported data?

2. In 1995 the Intergovernmental Panel on Climate Change established predictions about future global warming. Their results are based on a scenario of "business as usual," in which no changes are made in government regulations about greenhouse gas emissions. The predictions are that, as a result of enhanced greenhouse warming, the global mean temperature will rise 1.0 to 3.5°C by the year 2100 with a best estimate of 2°C. How do predictions made in the class compare with these predictions?

3. Based on information in the background readings, discuss what factors are involved in "global climate change" besides just temperature. What kinds of data should scientists combine into a model to get a more complete picture of the Earth System changes involved in global warming?

A teachable moment for graph scales!

Have students compare the two bar graphs on overhead transparencies. The Y-axis of the global temperature graph extends from 0.5°C to -0.5°C, while the Y-axis of the Great Lakes temperature graph extends from 2.5°C to -2.5°C. What we are experiencing is an error of scale. Plotting the two sets on the same axis, one for global and one for the Great Lakes, shows the true magnitude of the variation!

Sometimes people who report science choose their graph scales in such a way that data are distorted vertically. They can then claim that the trend is "not as great as it was feared," or is "even worse than anyone imagined." Students should be alert to how data are portrayed in the media, so they can become wise consumers of science information.

Review Questions

1. How reliable were the five sets of predictions in Activity A? Discuss the implications of basing conclusions on limited data and the patterns that could be inferred from considering each of these subsets.

2. How much data is needed to make reliable predictions? What kinds of data might be combined for a more reliable picture of global climate change?

3. Thinking back to your history classes, can you recall any events, inventions, or discoveries that may have contributed to increased temperatures?

4. Were the data used in this exercise collected by experimentation? Sometimes we learn about "the" scientific method and assume that the only way to do science is by experiments. Often in reality, more can be learned about Earth Systems through historical data that are mainly descriptive. To the following list add some observable data about the Earth Systems or the Great Lakes in particular that might be classified as:

Historical/Descriptive

- Phosphorus loading to each lake over the years
- Amount of toxin in birds in different regions
- Lake level changes
- Flood periods

Experimental

It may be difficult to find experimental data!
- Fish–growing experiments based on Great Lakes fishes

Answers to Review Questions

1. In trying to make predictions or conclusions based on limited data, it is hard to see the "whole picture." As the Great Lakes graph shows, conditions are more variable over short distances than when averaged worldwide. Also, trends are difficult to determine when data are only available from a limited time period. For instance, flooding may have been prevalent in a specific region over a period of 2-3 years. In looking at a graph of floods for a 10-year period, one might conclude that floods occur in an area two or three years out of every 10, when actually they occur only two or three out of every 100 years.

2. In order to make a reliable prediction, data should be obtained from as many years as possible using both human records and proxy data (data from which other information can be inferred, such as tree rings and fossil pollen as indicators of past climate conditions). In doing so, the researcher can better generalize data to a longer time frame. If just a few years of data are used, the researcher must list the limitations of data from a short time span.

3. Several events occurred after the late 1800s that created greater levels of pollution, including the levels of greenhouse gases. For example, the industrial revolution occurred in the late 1800s. Additionally, the automobile, invented in 1885, began to be mass produced in 1913. WW1 may have had effects also – either directly from fires and other factors, or indirectly from technological developments during the war.

EXTENSIONS

1. Local temperature variation may be different than either regional or global variation. Obtain local temperature data and plot this on a similar graph. How does it compare to the other data? What factors could cause differences between the data sets?

2. Working in groups, do research on the history of legislation regarding atmospheric conditions, such as those banning CFCs. Do you feel that these laws have had an effect? Explain your answer.

3. Do library research on the phenomenon of El Niño and its effects on global temperature.

4. Review the data provided on greenhouse gas concentrations (Activity B), and the changes in their levels over time. What relationships do you see between changes in global temperature and the levels of these gases?

Global and Great Lakes temperature data can be downloaded in the following manner:

ftp cdiac.esd.ornl.gov
Name: **anonymous**
Password: **YOU@your e-mail address**
Guest login ok, access restrictions apply.
ftp> **cd /pub/trends93**
ftp> **dir**
ftp> **cd temp**
ftp> **get glakes721** (or use "ftp> **get jones606**" for global anomalies)
ftp> **quit**
ftp> Goodbye
Access to CDIAC's anonymous FTP area is also available on the Internet: CDP@ORNL.GOV

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Aspen Global Change Institute. 1992. "Is it Getting Hot or Not? How When Affects What: Part II." *Ground Truth Studies*. Aspen, CO.

Boden, T. A., Kaiser D.P., Sepanski R.J. and Stoss F.W. 1993. *Trends '93: A Compendium of Data on Global Change*. Oak Ridge, TN: Carbon Dioxide Information Analysis Center. 984 pp.

Environment Canada. 1991. "Climate Change and Canadian Impacts: The Scientific Perspective," *Climate Change Digest* #CCD 91-01.

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Activity B: How are data from varying sources applied in problem identification?

We study concentrations in gases in the Earth's atmosphere to observe atmospheric changes: carbon dioxide is a by-product of the use of fossil fuels and a result of deforestation; methane is produced by cattle, rice fields, landfills, and naturally occurring wetlands; chlorofluorocarbons are made by people for use in refrigerators, air conditioners, foam, and insulation. When we observe changes in the concentrations of gases in the Earth's atmosphere and changes in global temperature, we are not necessarily attempting to prove a cause-and-effect relationship. Instead, we observe phenomena to see if different sets of data are following a similar trend, and we try to see what we can learn from this information. Studies of the Earth's history can also give us information about climate change. By studying bubbles of ice age air within glaciers and ice caps, scientists propose that there was less carbon dioxide and methane during colder times. Lower concentrations of the gases lessened the greenhouse effect and helped the Earth to stay cooler. Sometimes we can observe trends through collecting data over many years. In addition to the distant past, we have current measurements, as shown in the graphs used in the following activity.

Earth Systems Understandings

This activity focuses on ESUs 3 (science methods and technology) and 4 (interactions). Refer to p. VIII for a full description of the understandings.

Scenario Reference

Introduction: Understanding climate models.

Materials

- The provided gas concentration data

Also try the activity titled "Ice Cores — A Key to Unlocking Earth's Climatic Past" in *Activities for the Changing Earth System (ACES). 1993. Rosanne W. Fortner, Victor J. Mayer and David Eliot, Co-Directors. The Ohio State University Research Foundation.*

OBJECTIVES

This activity will allow students to:

- Observe how the atmospheric levels of four greenhouse gases have changed over time.
- Consider the relationship between the greenhouse gases and global temperature.

PROCEDURE

The accompanying graphs represent the concentrations of four greenhouse gases — methane, nitrous oxide, CFC11 and carbon dioxide — with the changes in their levels over time. Discuss as a class or in small groups the following questions:

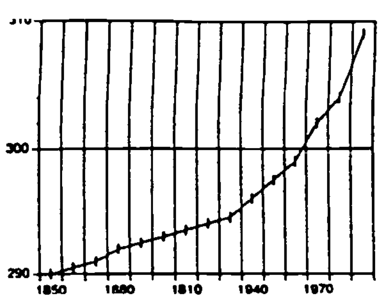
1. What is the apparent relationship between changes in global temperature (from Activity A) and the four gases?
2. What are the levels of these gases?
3. At what approximate date did the levels of the gases start to increase? Was this related to temperature?
4. Construct a hypothesis as to what you think may have caused these changes. How might such a hypothesis be tested?

Table 1. Major greenhouse gases

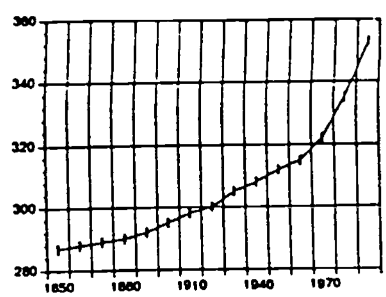
Gas	Assumed Concentration in 1880[a]	Concentration in 1990[b]	Projected Concentration in 2030[a]	Annual Growth Rate as of 1990[b,d]	Emissions from Human Activity in 1985	U.S. Share of Emissions in 1985	Contribution to Warming 1880-1980[a]	Major Sources[a]	Life Spans[h]
Carbon Dioxide (CO_2)	260-290 ppm	353 ppm	440-450 ppm	0.5%/yr	6-9 billion metric tons C[b]	20%	66%	Fossil fuel Combustion Deforestation	500 yrs
Methane (CH_4)	1.2 ppm	1.72 ppm	2.5-2.6 ppm	0.9%/yr	350 million metric tons CH_4[e]	10%	15%	Rice Fields, Cattle, Landfills, Fossil Fuel Production	7-10 yrs
Nitrous Oxide (N_2O)	290 ppb	310 ppb	340 ppb	0.25%/yr	4-10 million metric tons N[b]	NE[g]	3%	Nitrogenous fertilizers Deforestation Biomass Burning	140-190 yrs
CFC-11	0	0.28 ppb	0.5 ppb	4%/yr	3,000 metric tons[f]	22%	4%	Aerosol Sprays Refrigerants Foams	65-110 yrs
CFC-12	0	0.46 ppb	1.0-1.1 ppb	4%/yr	4,000 metric tons[f]	30%	5%	Aerosol Sprays Refrigerants Foams	65-110 yrs
Others	0	NE	NE	NE	NE	NE	7%		

[a] V. Ramanathan et al., "Trace Gas Effects on Climate," in *Atmospheric Ozone 1985*, Global Ozone Research and Monitoring Project Report No. 16, World Meteorological Organization, National Aeronautics and Space Administration (Washington, D.C., 1985).
[b] Intergovernmental Panel on Climate Change, *Scientific Assessment of Climate Change*, Summary and Report, World Meteorological Organization/ U.N. Environment Programme (Cambridge, MA, Cambridge University Press, 1990).
[c] U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, *Policy Options for Stabilizing Global Climate*, Draft Report to Congress (Washington, D.C., June 1990).
[d] Impact on warming over the next three decades of reducing U.S. EPA's (1990) projected annual emissions of each gas by an amount equal to 20 percent of 1985 levels. Expressed as a fraction of the impact of reducing projected annual carbon dioxide emissions by 20 percent of 1985 levels.
[e] R.J. Cicarone and R.S. Oremland, "Biogeochemical Aspects of Atmospheric Methane," Global Biogeochemical Cycles 2:299-327, 1988.
[f] J.K. Hammitt et al., *Product Uses and Market Trends for Potential Ozone-depleting Substances*, 1985-2000 (Santa Monica, CA: RAND Corp., May 1986).
[g] NE = no estimates.
[h] Drawn from *The Greenhouse Trap*, by Francesca Lyman, et. al., World Resources Institute, 1990.

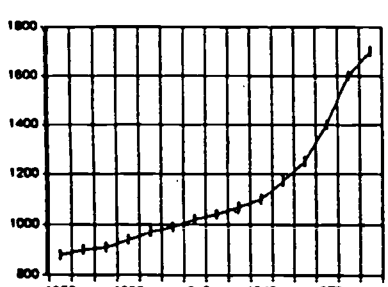
Reproduced from *Reporting on Climate Change: Understanding the Science*, with permission from the Environmental Health Center of the National Safety Council.



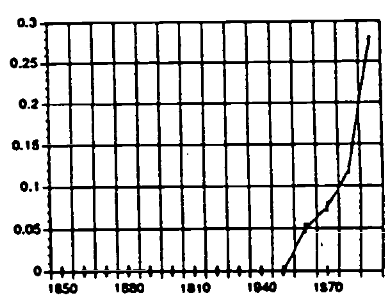
N2O Concentration, ppb



CO2 Concentration, ppm



CH4 Concentration, ppb



CFC11 Concentration ppl

Figure 1. Concentrations of greenhouse gases

Review Questions

1. We know that certain processes cause increased gas concentrations in the atmosphere. What steps can be taken to reduce these levels?
2. Does the warming trend appear to be consistent with the rise in gas concentrations? What kind of information can be obtained from our observations?

Extensions

Often students are given data to construct into a table or graph and are familiar with the origin of that data. Another important skill is to be able to interpret someone else's data. The data table in this activity gives students the chance to interpret what the figures mean. Examples are the following questions:

1. Why are the greenhouse gases in different units? CFCs seem to be occurring in small concentrations compared to CO_2 or N_2O. Is CFC at a lower concentration more of a concern than other gases in greater volumes? Does the table answer this question or is more research needed?
2. How could some of the data be displayed graphically?
3. Do research to compare the U.S. share of emissions shown in the data table with the U.S. share of world population. Students can discuss the comparison. Do the values parallel each other? Why or why not?

References

Warwick, Richard A. and Philip D. Jones. 1988. The greenhouse effect: Impacts and policies. *Forum for Applied Research and Public Policy* 3(3):48-62.

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National Safety Council. 1994. A Journalist's Guide. *Reporting on Climate Change. Understanding the Science.* Washington, D.C.: Environmental Health Center. For more information, contact: Environmental Health Center, National Safety Council 1019, 19th Street, N.W., Suite 401, Washington, D.C. 20036.

Answers to Questions

1. Students should brainstorm ideas to address the concerns regarding greenhouse gases. For example, policies could encourage carpooling and reforestation projects.
2. Both temperature and gas levels have shown increases over the years. This is an observation. The graphs alone do not show that the change in level of gases causes the rise in temperature. Students should observe the trends and think about how scientists infer relationships occurring between these phenomena on Earth.

Teacher's Notes

1. Students could use resources to better understand the nature of the greenhouse gases. For example, the role of CFCs in producing the ozone hole is far more significant than its effect as a greenhouse gas.
2. One example would be to make a pie chart showing the contribution to global warming of each compound.
3. This is one example of how students can transform what may appear to be static numbers into a workable and creative representation of data.

Activity C: How do greenhouse gases affect heat absorption?

The Earth's climate depends on the amount of solar radiation received and the atmospheric abundance of clouds and greenhouse gases. The main greenhouse gases are carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, water vapor, and ozone. Much of the high-energy, short-wavelength radiation from the sun passes through the Earth's atmosphere and hits the surface of the Earth. The energy that is not reflected off the surface is absorbed and re–radiated into the atmosphere, where much of it is absorbed by the greenhouse gases. This is known as the greenhouse effect.

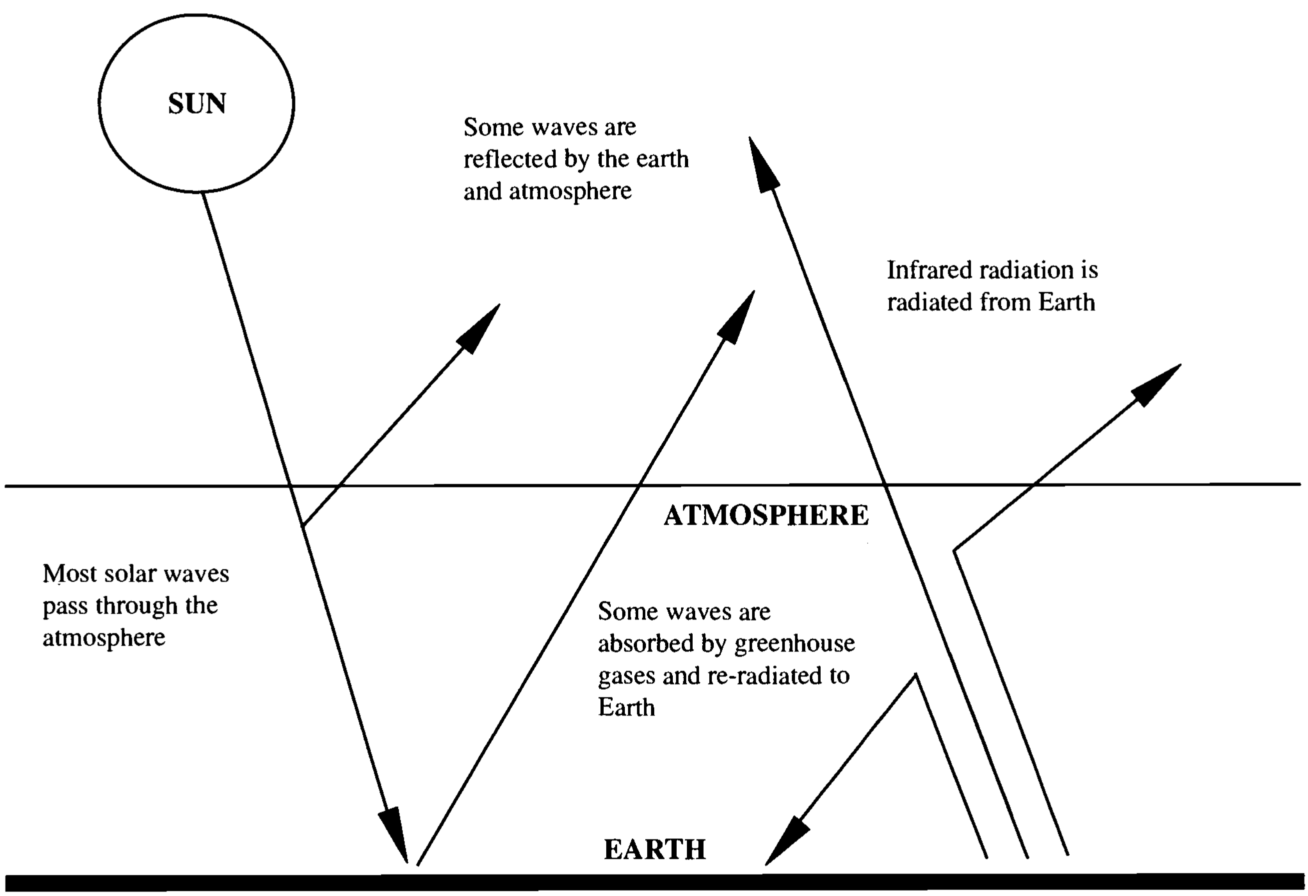


Figure 1. The greenhouse effect (adapted from Houghton, et. al., *Climate Change: The IPCC Scientific Assessment*, 1990)

In Activity B it became clear that certain gases have been increasing in concentration in the atmosphere on a timeline concurrent with increasing global temperature. In the following activity you will simulate a portion of the greenhouse system using carbon dioxide. The concepts studied in this activity include: *greenhouse gases, greenhouse warming, the greenhouse effect, thermal equilibrium, and experimental variables.*

OBJECTIVES

After completing this activity, each student will be able to:

- describe the components of the greenhouse effect
- explain the effect of CO_2 on the absorption of heat in the atmosphere.

PROCEDURE

1. Before the activity begins, the apparatus should be assembled by the teacher. Lubricate the bottom one–third of each thermometer with glycerine or other lubricant. Hold one of the thermometers with several layers of paper towels and gently push the thermometer through the hole in one of the rubber stoppers. Push until about 10 cm of the thermometer has passed through the other end of the stopper.

   CAUTION: DO NOT FORCE THE THERMOMETER THROUGH THE HOLE. THE THERMOMETER MAY BREAK AND CAUSE INJURIES.

   Make sure that you push the bulb end of the thermometer toward the small end of the stopper and through the opening. Repeat with the other thermometer and rubber stopper.

2. Wipe off the excess glycerine and then tape a small piece of white paper over one side of the bulb of each thermometer. The purpose of this paper is to shield the bulbs from the heat source. Make sure you affix the paper so that you can read the scale accurately.

3. Place 1 CO_2 cartridge in the empty cream whipper. Activate the cream whipper and "pour" the CO_2 from the cartridge into one of the 1–liter bottles. Make sure to empty the whipper completely.

4. Stopper the bottle containing CO_2 with one of the stopper/thermometer assemblies. Seal it with stopper grease or parafilm. Stopper the other 1–liter bottle in the same way. This bottle will have air in it. Label the first bottle "CO_2" and the second bottle "AIR".

Earth Systems Understandings

This activity focuses on ESUs 2 (stewardship), 3 (science methods and technology), and 4 (interactions). Extensions address ESUs 5 (change through time), 6 (Earth as a subsystem), and 7 (careers and hobbies). Refer to the introduction of this book for a full description of each understanding.

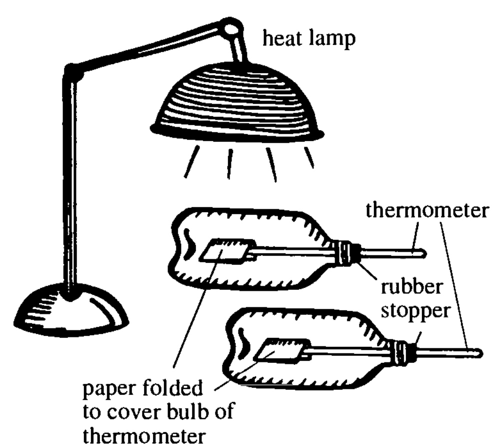
Scenario Reference

Introduction: Understanding climate models.

Materials Per Team

- 2 clear, empty, 1-liter plastic pop bottles
- cream whipper with one CO_2 cartridge
- 2 thermometers
- infrared radiation source (heat lamp)
- 2 #4 rubber stoppers with 1 hole in each
- 2 sheets of white paper
- transparent or masking tape
- parafilm or stopper grease
- thin book, sponge or piece of wood
- glycerine or other lubricant
- graph paper
- a meter stick

STRESS SAFETY: STUDENTS SHOULD WEAR GOGGLES AND PROTECT THEIR HANDS WHEN INSERTING THERMOMETER IN STOPPERS.



5. On a white piece of paper lay the two bottles down together on their sides. Support the necks of the two bottles with a thin book, sponge, or piece of wood. It is important that the pieces of paper you taped to the bulbs of the thermometers are on top and will shield the bulbs from the infrared heat source. Make sure that you can read the scale of each thermometer without moving the bottles.

6. Place the infrared heat source 0.5 m above the two bottles. Make sure that both bottles are equidistant from the heat source.

7. On your own paper, record the temperatures in each bottle before adding the heat lamp. Then turn on the infrared source and record the temperatures in the two bottles at 2-minute intervals for a total of 16 minutes. (You should have eight readings in addition to your original reading.)

8. At the end of 16 minutes, lower the infrared source to 0.25 m above the bottles and continue to record the temperatures in the two bottles at 2-minute intervals for another 16 minutes. (You should now have 16 readings in addition to your original reading.)

9. After you have completed recording the temperatures for a total of 32 minutes, turn off the infrared heat source and feel the two bottles to see if you can detect a difference in temperature.

10. Draw a line graph to show how the temperatures in the two bottles changed over time. Use a solid line for the temperatures from the bottle that contains air, and a dashed line for the temperatures from the bottle that contains CO_2.

Teacher's Notes

If you have available sources of N_2O you may want to have two or more groups try this activity using this gas for comparison purposes.

Students can calculate the slopes of both lines for comparison purposes.

Evaluation

1. What part of the greenhouse effect system does the infrared source represent?

2. What part of the greenhouse effect system is being represented by the 1–liter bottles?

3. Why was it necessary to shade the bulbs of the thermometers with pieces of white paper?

4. When the heating of the bottles was completed, which bottle felt warmer?

Answers to Evaluation Questions

1. Heat from Earth's surface.
2. The atmosphere.
3. To reduce the direct warming of the bulbs by the heat source.
4. The bottle containing CO_2 should have felt warmer.

5. In which bottle did the temperature increase faster? Explain why.

6. Was the rate of temperature increase for each bottle the same throughout the first 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.

7. How many times more heat energy was striking the two bottles after you lowered the infrared source to 0.25 m? How did this affect the temperatures in the two bottles?

8. Was the rate of temperature increase for each bottle the same during the second 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.

9. Is the pattern of change of temperature in each bottle the same? Explain why or why not.

10. How would you know when the apparatus is in thermal equilibrium?

11. Is Earth's atmosphere in thermal equilibrium at present? Explain.

12. Explain how the presence of CO_2 and other "greenhouse" gases in the atmosphere affect the heating of the atmosphere from an infrared source.

13. Explain fully how this activity relates to the greenhouse effect in Earth's atmosphere.

14. In this activity, what variables help to determine the temperature of the gases in the bottles?

15. Choose one of the variables (Question 14) other than the distance between the infrared heat source and the bottles, and describe how you would repeat the activity to determine how that variable affects the temperature in the bottles.

16. If human activity continues to add CO_2 and other greenhouse gases to Earth's atmosphere through burning of fossil fuels, deforestation, and other practices, predict how the average temperature of the atmosphere will change in the future.

Answers (continued)

5. The bottle containing the CO_2 should, because CO_2 absorbs infrared radiation more effectively than air.

6. Refer to the slopes of the lines. The temperature of the CO_2 should increase faster. Both lines flatten out as the system approached thermal equilibrium.

7. Four times – inverse square law. They should both increase.

8. The temperature of the CO_2 should increase faster than the temperature of the air.

9. Possibly not. The temperature of the CO_2 is likely to increase faster than the temperature of the air. After a certain time, both lines should flatten out.

10. The temperature in the bottles no longer increases.

11. Global warming appears to be occurring, which suggests that the atmosphere is not in thermal equilibrium.

12. Greenhouse gases transmit short–wave radiation from the Sun, but absorb long–wave radiation from the Earth. These gases absorb thermal radiation, thereby trapping it in the atmosphere.

13. Answers should address how increased amounts of greenhouse gases cause warming of the Earth's atmosphere.

14. Variables include, but are not restricted to: the strength of the heat source; the opacity of the plastic bottles; the distance between the bottles and the heat source; the concentrations of gases in the bottles; and the types of gases in the bottles.

15. Answers will depend on the variable chosen, but could include factors such as size of bottle, type of material comprising the bottle, heat source used, gas injected, etc.

16. Based solely on the factors listed, the temperature should be expected to increase.

There has been an increase in the amount of CO_2, N_2O, and other greenhouse gases in Earth's atmosphere in the last 150 years. This increase has been measured and recorded in a variety of ways. Much of it has been attributed to such human activities as deforestation and the burning of fossil fuels. The current rate of increase of CO_2 in the atmosphere is 0.5 percent per year. At this rate, computer models predict that the average global temperature could go up 3–5°C by the year 2050.

Topics for Discussion

1. Have students explain why the initial temperatures in the two bottles were not the same. Discuss what would have to be done to make them the same.

2. What are the important aspects of the apparatus that determine at what temperature thermal equilibrium is reached — include discussion about the size of the bottle, the concentrations of gases in the bottles, and the opacity of the plastic.

3. How "real" is the lab setup? There is a major difference between concentrations of greenhouse gases in the bottle(s) and in Earth's atmosphere. Discuss how an increase of just 2 or 3°C in the atmosphere could cause agricultural belts to migrate. (See *Science*, November 3, 1995, p.731.)

4. Have the students create a concept map illustrating the process of heat absorption in the atmosphere and the consequences that it could produce on the various Earth systems and human society.

Extensions

1. Earth is more than 4 billion years old. When did the atmosphere develop around the planet? Determine what role this played in the evolution of life. If the amount of greenhouse gases in the atmosphere continues to increase, what impact would this have on all the life systems and the planet?

2. Venus is a planet whose orbit around the sun is closest to Earth's orbit. It has experienced greenhouse warming for many thousands of years and has a mean surface temperature of 480°C. How did the atmosphere form? Could this happen to Earth if the gas composition of the atmosphere alters? Support your answers with evidence.

3. The National Oceanic and Atmospheric Administration (NOAA) is one organization that monitors changes in the oceans and atmosphere of the planet. Many scientists, such as meteorologists, oceanographers, atmospheric scientists, etc., focus on different areas in their work. Select one of these scientists and investigate the type of training required for his/her career.

4. The demand for energy will continue to grow as the human population increases. To tackle the problem of the greenhouse effect, gases such as CO_2, CH_4, and N_2O cannot continue to be pumped into the atmosphere. What alternative energy sources can be used to meet this increasing demand for energy? Select one of these energy sources and explain its advantages and disadvantages in relation to environmental impact. Also investigate how the public perceives this energy source. Support your answers with evidence.

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VIDEO

After the Warming. 1990. A co–production of Maryland Public TV, Film Australia, Wiseman (UK), Electric Image (UK) in association with Principal Film Company Ltd. (UK).

HELPFUL DEFINITIONS (VOCABULARY)

Greenhouse effect: "The trapping by atmospheric gases of outgoing infrared energy emitted by Earth. Part of the radiation absorbed by the atmosphere is returned to Earth's surface, causing it to warm" (Graedel and Crutzen, 1993, 430). Principal greenhouse gases are H_2O vapor, CO_2, O_3, CH_4, N_2O, CF_2Cl_2, and $CFCl_3$.

Thermal equilibrium: Balanced temperature regime achieved when the amount of heat leaving and entering a system are equal.

TEACHER BACKGROUND INFORMATION

National Geographic Society. 1993. Global Warming Debate. *Research and Exploration.* Vol. 9, No. 2, Spring Issue.
This journal comprises several articles surrounding the issue of global warming. It contains figures, photographs and discussions of modeling, policy, temperature, agriculture, and climate–related phenomena.

Moore, P. and G. Hunt. 1990. *The Atlas of the Solar System.* New York: Crescent Books. pp. 104-105.
The section concerning the atmosphere of Venus documents how the atmosphere developed and how the greenhouse effect on the planet evolved. Diagrams of this process, while small, are an excellent representation and could easily be enlarged. They could also be placed on transparencies. This would be a good way of allowing students to envision the process that may occur on Earth, should global warming (or an enhanced greenhouse effect) occur.

Matthews, S.W. 1990. Under the Sun — Is Our World Warming? *National Geographic.* 178(4):66-99.
This is a superb article that deals with the complete topic of global warming. Specifically, pages 72–77 concentrate on the influence of greenhouse gases on the process of global warming. Excellent illustrations and charts help to create an understandable account of the scientific processes involved.

Activity D: Why don't all scientists agree that global warming is in progress?

One of the tricky questions that scientists wrestle with is highlighted by a study of the variability of the weather. It is clear even from a short-term study that weather is constantly changing! How then can we sort out real climate change from simple variability?

Imagine trying to listen to a radio station that is full of static. The noise prevents you from getting a clear radio signal. The same is true for climate: *noise* (natural variability) may prevent us from detecting the *signal* that global climatic change is in progress. This is why it is extremely important to study weather patterns as far back as records go. As an example, *Reader's Digest* ran an article questioning global warming based on fifteen years of data whereas the *New York Times*, a month later, ran an article based on 1994 temperature data stating that global warming was occurring. Neither fifteen years nor one year of data can be sufficient. Many years of data are needed so that trends can be detected and people will know enough to detect a signal denoting climate change.

Think about it: the decade of the 1980s included the five warmest years in this century. In the '90s, major hurricanes and great floods created memorable weather history for the U.S. Are these events part of the noise, or are they a signal that the climate is changing?

Neither fifteen years nor one year of data can be sufficient. Many years of data are needed so that trends can be detected and people will know enough to detect a signal denoting climate change.

In addition to the uncertainty about how much the Earth will warm under global warming, there is an ongoing debate among scientists, politicians, and policy makers whether there will be global warming and whether it is already in progress. Both sides have supporting data, including highly technical devices for measuring temperature, and both groups of experts can sound very convincing.

In this activity, students watch a videotaped debate about global warming or read articles with conflicting claims. Their task is to analyze the complex issues that arise when scientists disagree.

Materials

Video
Two Views: Global Warming. 1992. Chicago: NYSTROM, Division of Herff Jones, Inc.

Articles

Benedick, Richard E. 1992. Equity and Ethics in a Global Climate Convention. *America.* May.

Broecker, Wallace S. 1992. Global Warming on Trial. *Natural History.* April.

Kerr, Richard A. 1995. Is the World Warming or Not? *Science.* February. Vol. 267, p. 612.

Singer, Fred. 1992. Warming Theories Need Warning Label. *The Bulletin of the Atomic Scientists.* June.

PROCEDURE

Watch the videotape as a group, and/or assign the articles for homework reading. Divide the class into groups of four or five people for discussion. Here are suggested discussion questions.

1. What are the most believable points presented by each side of the debate?

2. What references are given by each side? Do you feel the references are credible?

3. Are the two sides interpreting the same data in different ways, or do they have different data sets? Where were the data obtained?

4. Do you feel that in either of the views, fear is used? That is, do you think either side is using scare tactics to convince the audience?

5. Can your group reach a consensus as to which view you believe is correct? Or, are able to find some truth to each argument? Present your decision to the class. Explain why you have reached this decision.

6. Suppose an energy–use policy is being proposed, how much data would be sufficient as a basis for policy?

REVIEW QUESTION

After a public outcry demanding a remedy for global warming, you, as a governor of a Great Lakes state, must weigh the opinions of the two sides of the global warming issue and define a likely state policy that would lessen the effect of global warming. What side would you take? What are the strongest points that would defend your side of the issue? Explain the steps of your plan to resolve the public's understanding of the issue of global warming.

Great Lakes Climate Factors

One of the most difficult problems scientists have in talking with people about global climate change is the scale of the issue. People tend to view the world based on where they live and how long they have been alive. In global terms, both the time and space scales of individual human lives are infinitely small.

Global climate change, however, affects the entire planet on a time scale of centuries to millennia (1 millennium = 1,000 years). Humans are challenged to stretch their perception far enough to accommodate that amount of time. Having students visualize the variability of local weather may help them relate to variability of climate.

Climate is a complex combination of weather conditions, temperature patterns, and meteorological changes over long periods of time. Changes in the amounts and relationships of these atmospheric factors are of concern because of their impact on the *hydrosphere* (the water on the Earth's surface). The amount of water in lakes, rivers, soils, and the ground is directly related to the amount of precipitation and evaporation.

With a doubling of the amount of atmospheric carbon dioxide and increases in other greenhouse gases, hydrologic modelers have predicted a drop in the levels of the Great Lakes. An increase in annual precipitation is expected, but decreased runoff and higher evaporation rates will offset the additional moisture. Observing historical climatic data for the Great Lakes Basin may provide some insight into future change. This set of activities will consider relationships among Great Lakes precipitation, temperature, lake levels, and drought.

The Potential Effects of Global Climate Change on the United States, by the U.S. Environmental Protection Agency (1989), describes the effects of three global change models. The models are from Oregon State University (OSU), Geophysical Fluid Dynamics Laboratory (GFDL), and the general circulation model from the Goddard Institute of Space Studies (GISS). The models are discussed in "Introduction to the Great Lakes Scenarios." The following table predicts lake level changes as a result of CO_2 doubling in the atmosphere. All models demonstrate a reduction in lake levels from their average levels for the period of time

Earth Systems Understanding

This activity focuses on ESUs #3 (science methods and technology) and #4 (interactions), with applications to ESU #7 (careers and hobbies). Refer to the Framework for Earth Systems Education for a full description of each understanding (p. VIII).

Scenario Reference

Introduction: Understanding climate models, and #1, How will water resources in the Great Lakes Region be affected?

> **"The hydrologic cycle is a key component of the Earth's climate system which links the atmosphere, oceans, land and the biosphere. Improved understanding of the hydrological cycle is essential in order to resolve uncertainties in predicting future climate change."**
>
> *(From 1993-95 Priorities, IJC)*

1951–80. The data are not listed for Lake Ontario because lake levels are regulated for power production and the shipping industry.

Table 1. Lake level changes based on scenario models

Scenario Model	Lake Superior	Lake Michigan/ Huron	Lake Erie	Lake Ontario
GISS	-0.43 to -0.47 m	-1.25 to -1.31 m	-0.95 to -1.16 m	not applicable
GFDL	not applicable	-2.48 to -2.52 m	-1.65 to -1.91 m	not applicable
OSU	-0.39 to -0.47 m	-0.86 to -0.99 m	-0.63 to -0.80 m	not applicable

Activity A: How is the precipitation of the Great Lakes Basin related to lake level change?

Suggested Materials

- If CD-ROM is used, an MS-DOS computer is needed (The use of this additional information is optional.)
- The CD-ROM contains additional precipitation data and is the *International Station Meteorological Climate Summary* disk from the National Climatic Data Center, Asheville, NC 28801 (phone 704/ 271-4800); an atlas with city index will help students locate each reporting site
- Additional precipitation data are also available on the World Wide Web (see instructions on the following page).
- Additional lake level data are available from the U.S. Army Corps. of Engineers, Detroit District, PO Box 1027, Detroit, MI 48231-1027, either in hard copy or from their homepage at http://sparky.nce.usace.army.mil/

While average precipitation data exists for the Great Lakes Basin, data from individual reporting stations throughout the Basin may not always agree. In this activity students will have an opportunity to explore and use meteorological climate data available in an electronic format and to investige the relationships between monthly precipitation and lake levels (necessary data are provided in Figures 1 and 2).

Objectives

After completing this activity, students will be able to:

- Access and manipulate data on variables that can affect lake levels.
- Discuss how lake levels vary by month and by year.
- Explain the relationship of precipitation to lake levels.

Suggested Approach

1. To do this activity students can use the provided precipitation data from Green Bay (Figure 1) and the provided lake level data (Figure 2), or they can obtain data from other reporting sections within the Michigan–Huron basin, or from the other Great Lakes. Students can download data using the instructions provided on this page and in the *materials* section. Information for using the CD-ROM is provided on page 34.

2. Divide the class into five teams. Students then choose the five consecutive years with the lowest (or highest) lake levels and examine monthly precipitation for individual years. Students should pay particular attention to how precipitation varies by month and which months show the greatest change in lake levels. Have groups investigate different decades using the CD–ROM or web site data and look for unusually dry or wet conditions. Have them report their findings to the class. They may also investigate other parts of the country and compare them to the Great Lakes Basin.

Teacher's Note

Students can further develop this activity by obtaining information on each of the Great Lakes from the U.S. Army Corps of Engineers and downloading additional reporting stations by accessing the National Climatic Data Center homepage. Expand to match the range of data students have available.

Precipitation Data from the World Wide Web:

http://www.ncdc.noaa.gov
Click the Online Data Access button
Choose Anonymous FTP Archive – U.S. Monthly Precipitation for Cooperative and NWS Sites
You can choose your reporting site within your state.
With the cursor, highlight the data desired.
Copy it to a word processing file.
Transfer data to a spreadsheet format such as Excel, parse the data and place the decimal point where appropriate.
Graph the data.

Interpreting the Data

1. Do precipitation and lake levels vary together? Using Lakes Michigan/Huron level versus year data, select several recent years (since 1950) with exceptionally high or low lake levels. Examine the monthly precipitation and lake level data for these years. Are all months extreme? Describe any relationship you can detect between monthly precipitation and lake level changes.

2. Drought conditions existed throughout much of the Great Lakes Basin during 1988. Observe the Meteorological Climate Summary for Green Bay for 1988. Do the precipitation data support a drought period? Was 1988 an unusual year or one of many dry ones?

3. Make graphs of annual mean lake levels for all lakes. Look at lake level and precipitation data for 1963. How do the data sets compare? Is there anything unusual about this year? Using your graphs, make transparencies to overlay several lakes or place all lakes on a single graph scale. During periods when one lake is low or high, do the other lakes behave in a similar manner? Do lake levels change to the same degree?

4. In this activity, precipitation impact alone was investigated. What other variables could impact lake levels? Explain your answer.

Could high rainfall and low run-off conditions occur together? Can you think of how this could happen?

Answers to Interpreting the Data

1. There are different patterns that occur. There are years with high lake levels and high annual precipitation, while there are other years when these do not parallel one another. The heaviest precipitation can be observed during different months as can peak lake levels depending on the year. Monthly changes in precipitation and lake levels may vary.

2. 1988 was not the driest year recorded although the annual precipitation value was lower than average for Green Bay from 1950 to 1989. Precipitation levels were extremely low in May and June. On the other hand, the level for November was one of the highest recorded among 40 years of data.

3. 1963 displayed low precipitation and low mean lake levels. Students can observe how monthly and yearly changes vary between the lakes. They can also observe the differences between Lake Ontario and the other lakes remembering that Lake Ontario's levels are regulated by human activities.

4. Students can think about how rainfall plays a role in the hydrologic cycle and what other sources of input affect lake levels. Students should discuss weather patterns and variables such as temperature, humidity, storms, wind, and extreme fluctuations in any of these. In addition, water being withdrawn for human, industrial, and shipping activities could affect lake levels as could demand on groundwater supplies.

Review Questions

1. How does precipitation relate to lake levels? During periods when one lake is low or high, how do the levels of the other lakes compare?

2. Describe a probable chain of events that might occur if three successive years in the Lake Superior Basin had low precipitation. Synthesize the impacts on lake level in Superior and downstream lakes. How would people notice these changes?

Extensions

1. Enlist the aid of the National Weather Service meteorologist in your area, or use back issues of the daily newspaper's weather column, to develop a data set that goes back at least five years, but preferably to the year most of the students were born. Many daily newspapers have a year's weather summary at the end of December, and collecting these from back issues can provide interesting comparisons from year to year. Students will remember extremes in the recent years: very cold (or warm!) winters, wet summers, long droughts and the like. They may enjoy reading "Where have all the winters gone?" in the December 1993 issue of *WeatherWise* magazine.

2. Have students prepare meaningful charts and graphs of the data available to the class. Then calculate averages of temperature, rainfall, lake water temperature, date of first frost, etc., over the 5–15 year period, and add the average line to the graphs in red. Compare daily weather, data they collect, to that average. Based on the kinds of weather differences they observe, they should prepare a short talk about local weather in relation to global climate change, for a meteorologist to give on the evening news broadcast.

3. As a class, produce an ongoing weather database for your school, with measurements added at regular intervals and charts kept to compare school weather with the official National Weather Service reports for your city. Analyze reasons for differences between the measurements, and study national weather patterns for atmospheric phenomena that could explain local weather.

Answers to Review Questions

1. Precipitation is one of many factors to consider, because other phenomena affect lake levels such as evaporation, runoff, and groundwater. A significant change in precipitation from one month to the next, therefore, may not necessarily have a drastic impact on lake levels, but precipitation acting with other factors in the right combination may affect the lakes. During periods when one lake is high or low, other lakes, with the exception of Ontario, sometimes follow similar trends. Yearly changes may vary by degree with each lake. Students should consider whether the size of the lake determines how much the lake level changes from year to year.

2. If three successive years had low precipitation, groundwater levels would be lower. There would be less runoff from the surrounding areas as well. With several potential sources of input to the lake in less supply, the lake level could drop. Other lakes would likely show dropped levels. There might be a need to conserve water and people would notice dry conditions in the soil and vegetation in the Great Lakes Basin.

What will the weather be like today?

Technology Procedure for Optional CD–Rom

1. Boot the CD–ROM disk. Type ISMCS (the disk acronym) and press Enter.

2. After several introductory screens, a world map will appear. The small white box allows the user to choose an area to study. Move the box to the United States with the arrow keys. Press Enter. Use the enter and arrow keys to zoom in on the Great Lakes Basin. The shift and arrow keys can be used together for fine adjustment of the box size.

3. A new screen will show the contents of the box as a full screen display. Function keys are highlighted at the bottom of the screen. Select F3 DATA, then choice 1 – SMOS/SOCS stations.

4. Continue to reposition the highlighted box and press Enter to zoom in on the portion of the Basin desired, press F4 (SELECT) to go to the station selection menu Choose 3 – by Name. Press Enter. A station list sorted by name will appear.

5. Select the station site by its name. (Using an atlas with city index will help in locating reporting sites.) From the station table menu select *Total Precip vs Yr-Mth* (Total precipitation for year and month). Press Enter.

6. View the data on the screen or output it to a separate file for manipulation or printing later. The Print screen command can be used to print data immediately. To save data to a file, press F2.

References

U.S. Environmental Protection Agency. 1989. *The potential effects of global climate change on the United States* EPA-230-05-89-050.

Schneider, S. 1989. The changing climate. *Scientific American* September:70-79.

National Climatic Data Center. *International Station Meteorological Climate Summary* CD-ROM, Asheville, NC 28801; Phone: 704/271-4800.

Figure 1. 1949-1990 Precipitation data, Green Bay, Wisconsin

INTERNATIONAL STATION METEOROLOGICAL CLIMATE SUMMARY

" :STA 726450 I KGRB I GREEN BAY WSO AP ,WI,US"

:LAT 44 29N :LONG 088 08W :ELEV 682(ft) 208(m) :TYPE NOAA SMOS V2.1 07021992

35 - Year/Month TOTAL PRECIPITATION (INCHES) from Daily Obs.

POR: : 1949-1990

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
1949	-	-	-	-	-	-	-	-	1.25	1.05	1.5	1.17	-
1950	2.64	1.45	2.49	3.39	1.5	3.11	6.5	2.72	2.2	1.14	1.12	1.84	30.1
1951	0.87	1.72	2.66	4.79	0.89	2.3	4.12	5.5	2.93	4.82	1.66	1.09	33.35
1952	2.06	0.7	1.98	1.57	2.92	2.36	3.82	2.06	0.82	T	2.24	1.45	21.98
1953	1.1	3.56	1.94	5.52	1.41	1.9	3.15	2.05	2.02	0.22	0.39	1.59	24.85
1954	0.43	0.98	1.11	4.45	3.22	4.38	2.94	1.61	5.78	5	0.89	0.42	31.21
1955	0.78	1.37	1.4	2.4	2.39	3.25	4.78	0.9	0.76	3.58	1.04	0.89	23.54
1956	0.56	0.6	1.86	1.45	4.66	3.9	5.85	3.09	1.65	0.65	2.13	0.87	27.27
1957	0.35	0.43	0.46	2.93	5.28	2.48	3.18	3.46	2.15	1.35	3.52	1.59	27.18
1958	0.42	0.16	0.5	2.56	1.27	1.82	2.07	2.68	3.2	2.25	1.34	0.16	18.43
1959	1.04	1.98	1.87	2.84	3.86	1.26	4.21	2.71	5.17	3.27	1.47	2.85	32.53
1960	1.04	0.48	1.21	3.13	7.75	3.07	1.87	3.52	3.09	2.32	0.69	0.1	28.27
1961	0.31	0.93	2.12	1.67	1.42	4.31	4.91	2.84	5.02	3.34	2.6	1.27	30.74
1962	1.27	2.02	1.13	2.55	2.86	4.35	2.7	2.88	3.87	1.94	0.84	1.03	27.44
1963	0.68	0.59	2.58	0.98	1.54	2.67	2.77	2.07	3	0.73	1.63	0.73	19.97
1964	1.14	0.26	1.76	2.55	4.14	1.05	4.55	2.72	6.74	0.44	2.07	0.7	28.12
1965	0.93	0.85	2.38	3.62	3.95	1.89	1.96	3.38	7.8	1.32	2.19	2.31	32.58
1966	1.18	2.25	2.46	1.38	1.28	1.09	4.19	2.65	1.21	0.72	1.58	1.65	21.64
1967	2.52	0.84	1.13	2.77	2.45	8.47	1.96	2.43	0.46	4.71	1.66	1.17	30.57
1968	0.94	0.45	0.97	4.84	3.1	6.97	2	2.66	3.31	1.01	1.01	2.69	29.95
1969	2.6	0.04	1.04	2.86	2.66	7.62	2.51	1.19	2.03	3.46	0.43	1.43	27.87
1970	0.73	0.23	1.07	1.61	5.76	1.11	4.02	1.25	6.11	2.98	2.68	1.24	28.79
1971	1.6	2.03	2.04	1.05	1.67	1.87	3.44	2.99	3.36	2.01	3.21	3.15	28.42
1972	0.65	0.96	2.19	1.45	0.82	2.25	1.85	5.86	5.76	1.84	1.15	2.49	27.27
1973	1.86	0.72	2.43	3.23	8.21	3.2	1.93	2.57	2.91	3.96	1.45	2.41	34.88
1974	1.71	1.17	1.07	2.62	4.46	4.91	4.25	1.61	1.05	1.72	2.09	1.67	28.33
1975	1.52	1.48	3.44	2.35	2.79	5.27	1.78	9.04	3.18	0.36	3.42	0.84	35.47
1976	1.72	1.33	3.65	2.44	2.42	0.31	2.96	1.15	0.28	0.82	0.16	0.61	17.85
1977	0.67	1.38	4.68	3.33	2.47	2.27	2.13	2.37	2.44	1.36	2.7	2.31	28.11
1978	1.33	0.35	0.31	3.44	3.38	2.72	6.03	4.36	4.82	2.33	2.93	1.3	33.3
1979	1.78	1.17	4.49	1.93	3.01	2.21	3.55	5.97	0.76	2.72	2.49	1.28	31.36
1980	1.92	0.35	1	2.73	1.77	3.82	1.87	7.31	3.42	1.79	1.25	1.35	28.58
1981	0.12	2.76	0.42	4.22	0.56	2.63	0.83	3.37	3.25	3.44	1.08	1.1	23.78
1982	1.34	0.14	1.95	2.66	2.74	2.67	5.1	2.91	1.43	1.2	4.51	2.5	29.15
1983	0.72	1.46	1.52	1.39	4.8	1.82	3.76	5.27	3.59	2.24	2.63	1.18	30.38
1984	0.59	1.59	1.64	3.33	1.65	5.6	3.17	3.78	5.66	4.92	2.55	1.72	36.2
1985	0.86	2.55	2.7	2.24	2.58	2.21	4.03	8.03	3.65	2.72	4.96	1.83	38.36
1986	0.6	0.83	2.48	2.26	1.15	4.06	4.95	3.85	7.51	1.89	1.27	0.48	31.33
1987	0.47	0.39	1.53	2.33	2.58	1.83	2.18	3.41	1.57	1.76	3.07	2.04	23.16
1988	1.79	0.73	1.1	2.53	0.06	0.67	2.34	3.47	4.11	1.96	4.43	0.84	24.03
1989	0.41	0.38	2.88	0.49	4.22	1.56	2.27	1.05	0.58	4.76	1.25	0.55	20.4
1990	0.64	0.58	3.25	1.28	3.99	10.29	2.93	2.51	5.13	2.34	1.61	2.1	36.65

* = INCOMPLETE
\- = MISSING DATA
\# = EXCESSIVE MISSING DATA - VALUE NOT COMPUTED

FEDERAL CLIMATE COMPLEX ASHEVILLE

Figure 2. 1949-1993 Michigan-Huron lake levels by month (meters) based on a network of gages

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
1949	176.20	176.19	176.19	176.26	176.31	176.34	176.38	176.34	176.22	176.14	176.02	175.94	176.21
1950	175.96	175.99	176.02	176.17	176.27	176.34	176.42	176.44	176.43	176.40	176.34	176.35	176.26
1951	176.34	176.34	176.41	176.58	176.75	176.82	176.91	176.93	176.92	176.93	176.95	176.95	176.74
1952	176.95	176.96	176.96	177.08	177.17	177.22	177.26	177.28	177.22	177.06	176.94	176.92	177.08
1953	176.85	176.82	176.83	176.91	177.00	177.07	177.12	177.11	177.02	176.92	176.81	176.74	176.93
1954	176.63	176.60	176.64	176.71	176.83	176.92	176.96	176.94	176.90	176.98	176.95	176.89	176.83
1955	176.83	176.78	176.76	176.82	176.88	176.91	176.88	176.79	176.64	176.54	176.46	176.38	176.72
1956	176.31	176.30	176.32	176.37	176.50	176.57	176.62	176.62	176.56	176.45	176.37	176.29	176.44
1957	176.22	176.19	176.17	176.20	176.28	176.35	176.43	176.38	176.33	176.24	176.21	176.16	176.26
1958	176.15	176.13	176.12	176.14	176.12	176.12	176.15	176.11	176.07	175.98	175.91	175.81	176.07
1959	175.75	175.75	175.79	175.92	176.06	176.11	176.12	176.12	176.10	176.10	176.13	176.12	176.01
1960	176.14	176.16	176.14	176.24	176.50	176.64	176.72	176.77	176.73	176.64	176.57	176.48	176.48
1961	176.38	176.31	176.33	176.36	176.42	176.44	176.46	176.45	176.43	176.38	176.32	176.24	176.38
1962	176.20	176.17	176.19	176.26	176.34	176.37	176.36	176.32	176.26	176.17	176.06	175.97	176.22
1963	175.89	175.85	175.85	175.94	176.02	176.06	176.04	176.03	175.98	175.90	175.80	175.71	175.92
1964	175.63	175.59	175.58	175.61	175.74	175.76	175.78	175.77	175.76	175.70	175.65	175.62	175.68
1965	175.60	175.62	175.67	175.77	175.94	176.00	176.02	176.04	176.07	176.10	176.07	176.09	175.92
1966	176.10	176.08	176.13	176.20	176.26	176.30	176.28	176.24	176.17	176.08	176.01	176.08	176.16
1967	176.07	176.07	176.06	176.23	176.35	176.45	176.50	176.48	176.40	176.34	176.34	176.32	176.30
1968	176.29	176.30	176.27	176.35	176.40	176.47	176.55	176.58	176.60	176.57	176.50	176.48	176.45
1969	176.47	176.47	176.45	176.54	176.70	176.82	176.94	176.95	176.86	176.78	176.73	176.64	176.70
1970	176.59	176.56	176.53	176.58	176.68	176.76	176.80	176.78	176.77	176.73	176.69	176.67	176.68
1971	176.63	176.62	176.68	176.76	176.86	176.94	176.96	176.96	176.90	176.84	176.76	176.75	176.80
1972	176.73	176.65	176.65	176.72	176.88	176.93	176.99	177.05	177.07	177.03	177.00	176.96	176.89
1973	176.98	176.95	176.98	177.10	177.20	177.30	177.30	177.29	177.21	177.13	177.04	177.00	177.12
1974	176.95	176.97	177.00	177.07	177.19	177.28	177.32	177.26	177.15	177.04	176.98	176.91	177.09
1975	176.87	176.86	176.87	176.92	177.06	177.14	177.15	177.10	177.07	176.95	176.87	176.82	176.97
1976	176.76	176.75	176.87	177.02	177.11	177.15	177.15	177.08	176.95	176.80	176.64	176.51	176.90
1977	176.42	176.38	176.44	176.56	176.57	176.55	176.56	176.54	176.53	176.50	176.50	176.51	176.50
1978	176.48	176.45	176.43	176.51	176.61	176.67	176.69	176.68	176.71	176.70	176.62	176.54	176.59
1979	176.51	176.48	176.54	176.71	176.88	176.95	176.98	177.00	176.96	176.88	176.83	176.81	176.79
1980	176.78	176.72	176.68	176.77	176.84	176.90	176.93	176.93	176.90	176.82	176.72	176.65	176.80
1981	176.59	176.56	176.60	176.67	176.75	176.80	176.82	176.81	176.80	176.73	176.66	176.59	176.70
1982	176.51	176.46	176.45	176.56	176.62	176.66	176.69	176.69	176.65	176.62	176.60	176.67	176.60
1983	176.67	176.66	176.68	176.76	176.90	177.02	177.02	176.98	176.93	176.87	176.77	176.74	176.83
1984	176.70	176.70	176.72	176.81	176.91	177.01	177.06	177.04	177.02	176.96	176.93	176.88	176.90
1985	176.88	176.86	176.98	177.14	177.24	177.25	177.23	177.19	177.20	177.16	177.19	177.20	177.13
1986	177.14	177.11	177.12	177.23	177.28	177.33	177.39	177.39	177.38	177.50	177.38	177.26	177.29
1987	177.18	177.10	177.06	177.07	177.06	177.07	177.04	176.99	176.90	176.79	176.70	176.68	176.97
1988	176.63	176.60	176.57	176.67	176.70	176.67	176.61	176.57	176.48	176.42	176.43	176.42	176.56
1989	176.38	176.33	176.32	176.41	176.44	176.56	176.57	176.54	176.47	176.34	176.27	176.18	176.40
1990	176.15	176.16	176.19	176.27	176.35	176.44	176.51	176.49	176.45	176.41	176.39	176.39	176.35
1991	176.36	176.31	176.33	176.48	176.60	176.66	176.64	176.59	176.48	176.40	176.38	176.40	176.47
1992	176.38	176.36	176.38	176.44	176.53	176.52	176.54	176.53	176.52	176.49	176.52	176.54	176.48
1993	176.54	176.51	176.48	176.58	176.70	176.82	176.91	176.88	176.83	176.76	176.70	176.64	176.70

Source: U.S. Army Corps of Engineers, Detroit District, 1995.
Referenced to International Great Lakes Datum 1985.

Activity B: What extremes of climate characterize the Great Lakes region?

The dynamic climate of North America has periods of drought and wetness that occur frequently. What characterizes a drought? Are all droughts alike in their origin and impact? Meteorologists recognize different types of drought as shown:

Meteorological drought occurs when there is significantly below-normal precipitation (rainfall and snowfall) over a long period of time. The degree of moisture shortage and the length of time it takes for a meteorological drought to develop varies from region to region.

Hydrological (or water supply) drought occurs when a lengthy meteorological drought causes a sharp drop in the levels of ground water, rivers and lakes. For example, a lack of winter snowfall has a serious impact on the availability of water for a region in the following year.

Agricultural drought occurs when low soil moisture and scarce water supplies stunt crop growth, reduce crop yields, and endanger livestock.

Source: Canadian Climate Center, 1992.

Associated with hydrologic drought are decreased soil moisture, lower stream and river flows, and lower groundwater levels.

One method used to measure the magnitude and severity of drought is the Palmer Hydrologic Drought Index (PHDI). It is used to measure long–term precipitation, precipitation runoff, and groundwater levels. The index identifies each geographic region by how much it differs from normal amount of wetness.

The National Climate Information Disk, a CD–ROM from the National Climatic Data Center of NOAA, contains PHDI, precipitation and temperature data from 1895 through 1989. Monthly or seasonal maps of temperature and precipitation may be generated. The maps indicate how conditions vary from the "normal" conditions (the average of the last three decades).

Earth Systems Understandings

This activity focuses on ESUs #3 (science methods and technology), #4 (interactions), and #5 (change through time). Refer to the Framework for Earth Systems Education for a full description of each understanding.

Scenario Reference

#1, How will water resources of the Great Lakes region be affected?

Materials

- Palmer Hydrological Drought Index, Precipitation Departure and Temperature Departure Maps
- CD–ROM: The National Climate Information disk can be ordered separately and operated with an MS–DOS computer with color graphics. Hard copies of Palmer Hydrological Drought Index, Precipitation Departure and Temperature Departure Maps require graphics capability with EPSON compatible printers or HP Laser Jet Series II and III printers.

Student's Surf

See the National Climatic Data Center's homepage for interactive drought, precipitation, and temperature graphs. Instructions follow this activity.

Teacher's Note

Departure is the difference of a variable from its mean, or the difference of an observed value from a theoretical value.

Teacher's Example

The CD–ROM needs a command to start the video animation.

D:\ VAPHDI/FLIX 1980 is one example.

Objectives

After completing this activity, students will be able to:

- Describe applications of the Palmer Hydrologic Drought Index.
- Interpret precipitation and temperature departure maps, comparing them to the PHDI.
- Describe usefulness of monthly and seasonal precipitation and temperature departure maps.
- Infer climate trends through use of precipitation, temperature and PHDI maps.

Procedure

Monthly or seasonal data may supply valuable information about climatic trends. Data can be selected from the optional CD–ROM to make into a printed map.

1. Examine the accompanying maps. Try to detect any relationship between the categories (precipitation departure, temperature, and drought index) in the Great Lakes Basin. Look for trends throughout the seasons. Could the preceding seasons have predicted the situation in July?

2. How do the different categories of maps vary? For example, are there regions with drought and high precipitation or drought and low precipitation? Is one attribute normal while the others are above or below normal? What patterns can you detect? Look for different combinations of drought index, precipitation, and temperature.

3. The optional CD–ROM provides additional maps for students' use. To start the CD–ROM type SLICK at the DOS prompt. A directory will appear. Choose whichever data type desired and press Enter. From the list of files, select month and year desired. Type V to view map. To print the map, copy it onto the hard drive along with the display software.

The CD–ROM also has an animation of annual amounts of wetness or drought in the United States. Drought regions are represented by red circles and wet regions by blue circles. The purpose of the movie is to aid in comparing the geography and timing of wet and dry periods.

4. At the prompt for the CD–ROM drive, change to the VAPHDI directory. Type FLIX followed by the decade desired. Then view the animation. Press Q or Esc to stop the movie.

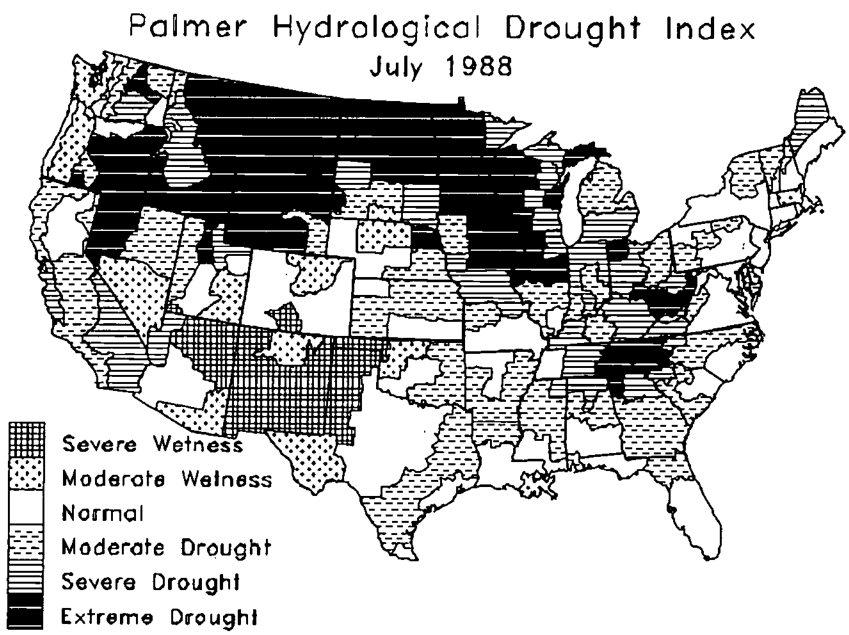

Figure 1.

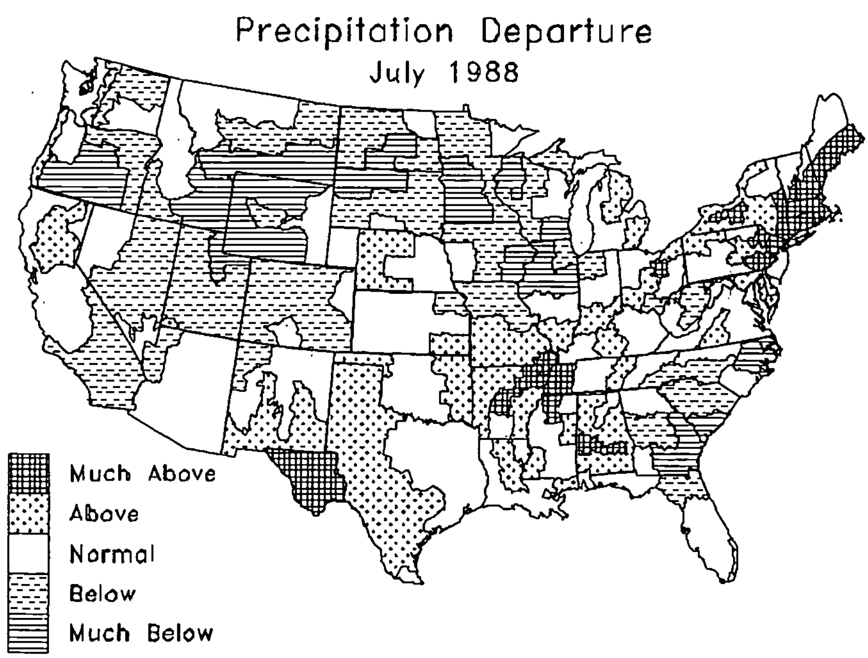

Figure 2.

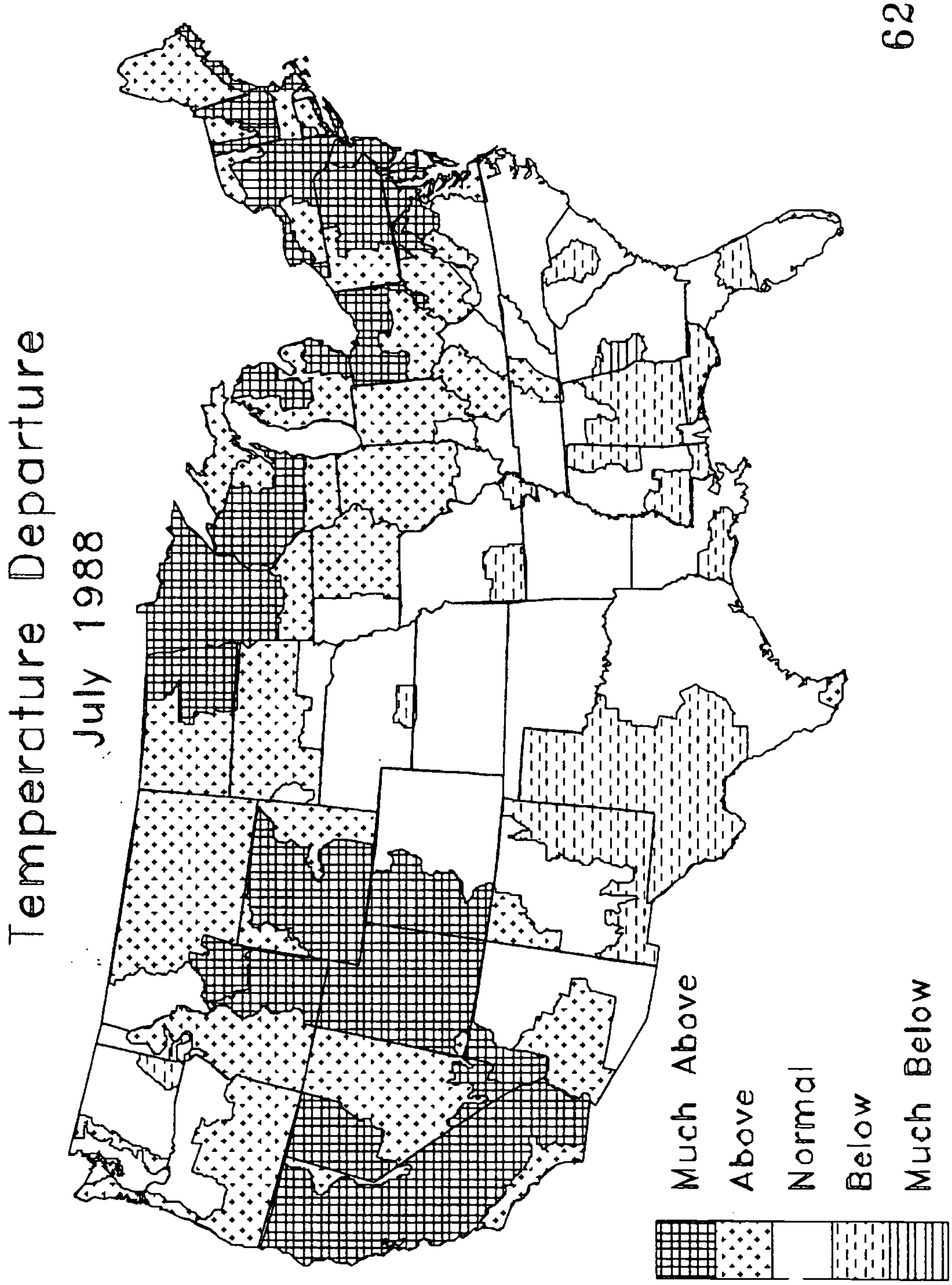

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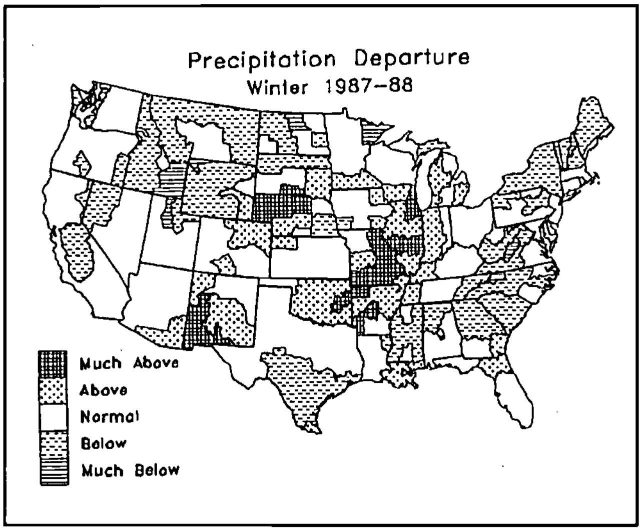
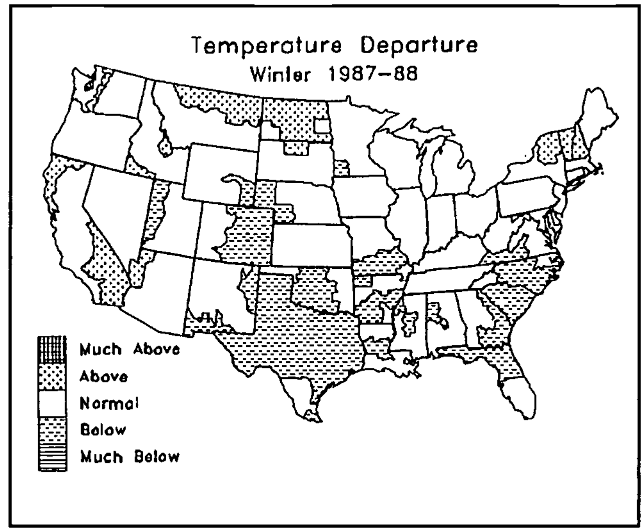
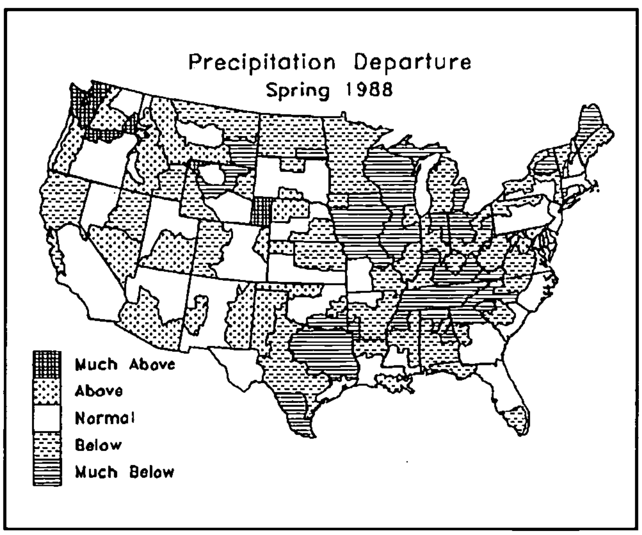
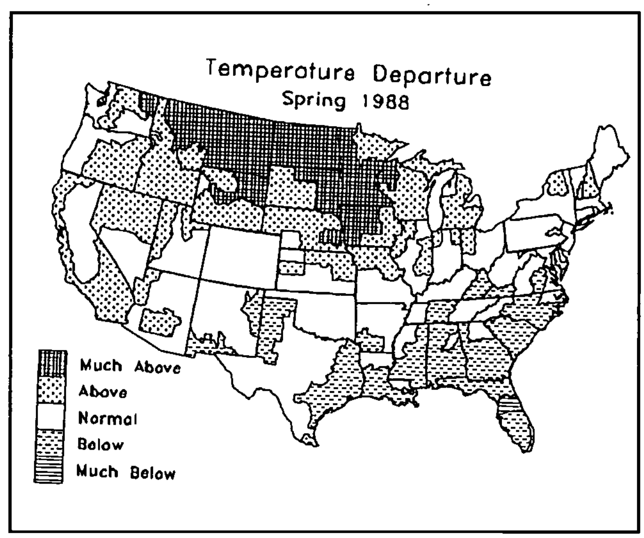
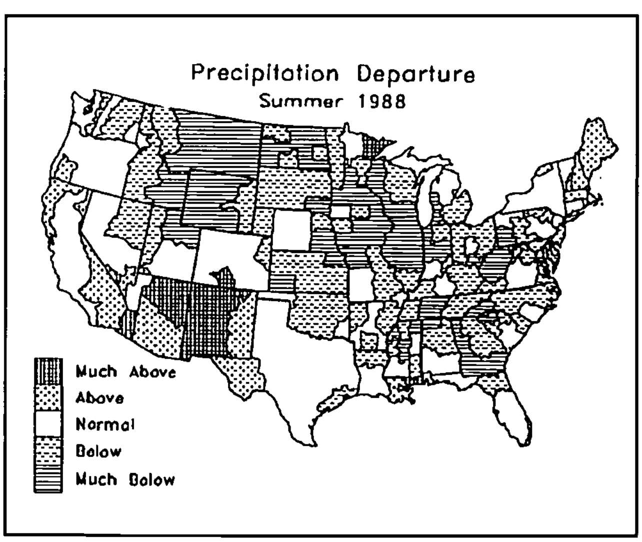
Figure 3.

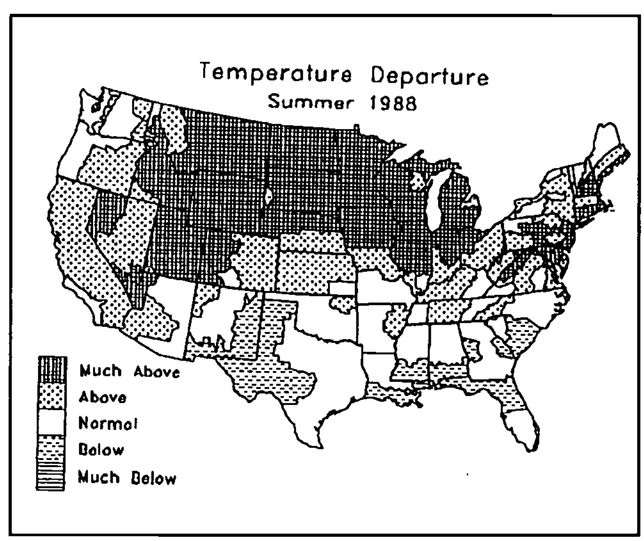

Precipitation Departure
Winter 1987–88
Much Above
Above
Normal
Below
Much Below


Temperature Departure
Winter 1987–88
Much Above
Above
Normal
Below
Much Below


Precipitation Departure
Spring 1988
Much Above
Above
Normal
Below
Much Below


Temperature Departure
Spring 1988
Much Above
Above
Normal
Below
Much Below


Precipitation Departure
Summer 1988
Much Above
Above
Normal
Below
Much Below


Temperature Departure
Summer 1988
Much Above
Above
Normal
Below
Much Below

Interpreting the Data

1. Look at the Precipitation Departure Map for July 1988. What was going on in the country's weather then? Compare the conditions on the Temperature Departure and PHDI maps for the same month. Do the conditions agree? Suggest a hypothesis to explain your answer.

2. Look at seasonal Precipitation and Temperature Departure Maps from winter 1987 through spring 1988. How do the conditions relate to the situation in July? Could predictions have been made for July based on seasonal maps, or would it have been necessary to consider other factors?

Review Questions

1. What is the value of looking at several types of data before making conclusions?

2. What is the value of having a sequence of maps to provide insight into climatic changes?

3. What kinds and amounts of additional data would students like to have before deciding if current climate indicates global change?

Extensions

1. Discuss as many impacts as you can imagine resulting from a drought in the Great Lakes Basin. Draw a concept map to illustrate your ideas. Some possibilities would be the effect on agriculture, industry, personal water use — homes, lawns, etc. Another possibility to incorporate would be the effect on water prices. How are economic, environmental, social, and political themes related to this situation? How are these factors interrelated when a drought causes water shortage for everyone?

Answers to Interpreting the Data

1. For many regions, the conditions agree. There are some instances, however, when they do not agree. Students should consider the possibility that high temperatures, high rainfall, and drought conditions can exist simultaneously in a particular area.

2. Students should discuss their interpretations of the maps. Looking at one year's data cannot indicate whether there is a predictive signal.

Answers to Review Questions

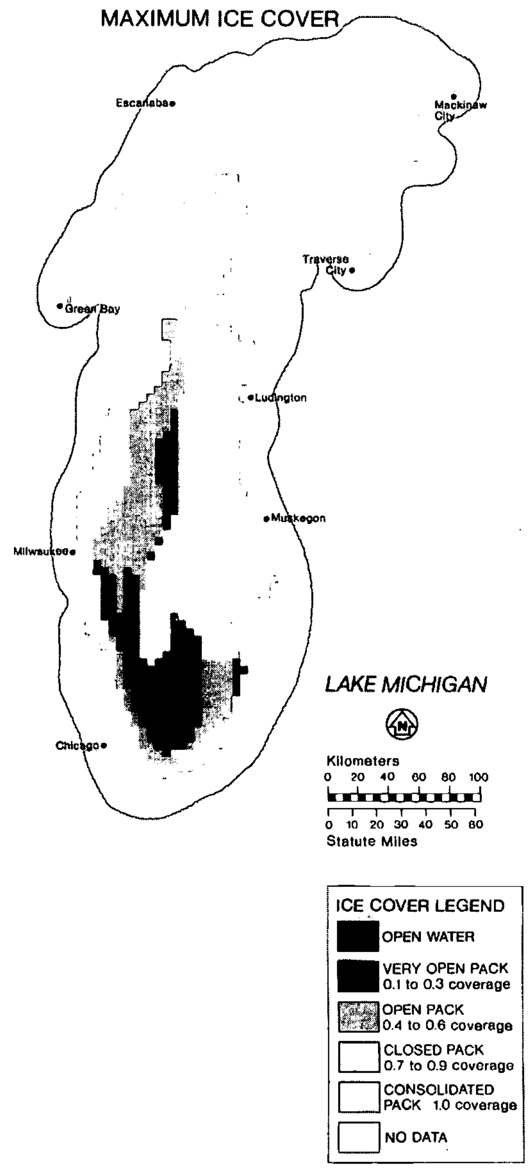
1. Looking at several types of data allows for a well–rounded approach to investigations. One can see if several types of data correlate or if one set of data simply gives unusual results.

2. Students should consider how trends may be observed in examining data over time.

3. Data on global temperature trends would contribute to an understanding of climate change. Historical evidence would support observations and comparisons over a long period of time.

2. Each year, the St. Lawrence Seaway closes down for winter because of ice in the locks. Shipping effectively ceases for a certain portion of the year. At the same time, winter recreation begins in earnest with ice boating, ice fishing, snowmobiling, and such on the frozen lakes.

   A study of the way ice forms on the Great Lakes is important for an understanding of the potential impacts of global warming on recreation and shipping. Students can examine how ice forms in normal years on each lake, describe the kinds of areas where ice first forms, and where it lasts longest in a normal winter. They will then interpret probable causes of ice formation on the Great Lakes and speculate on how global warming may affect the normal patterns. They can suggest how ice patterns, in conjunction with other hydrologic and atmospheric changes, will affect human activity in the region.



The material necessary for this extension is the *Great Lakes Ice Atlas* [GLERL Contribution No. 299 (for Macintosh with lower than system 7.0). 1983. National Oceanic and Atmospheric Administration. Great Lakes Environmental Research Laboratory. Ann Arbor, MI 48104]. There is also a version available for DOS machines.

Great Lakes ice conditions over a twenty-year period are represented in digitized form. Each of the five Great Lakes is portrayed showing areas of maximum, minimum, and normal ice accumulation, as well as observation density for December to April from 1960–1979. Ice cover is presented in accompanying tables.

References

Great Lakes Commission. *A Guidebook to Drought Planning Management and Water Level Changes in the Great Lakes* [The Argus II Building, 400 Fourth St., Ann Arbor, MI 48103-4816]

Canadian Minister of the Environment, Minister of Supply and Services. 1992. *Drought* Fact Sheet. [Atmospheric Environment Service, Canadian Climate Centre, 4905 Dufferin Street, Downsview, Ontario M3H 5T4]

GLERL. 1983. *Great Lakes Ice Atlas* Contribution No. 299. National Oceanic and Atmospheric Administration.

Houghton, R.A. and G.M. Woodwell. 1989. Global Climate Change. *Scientific American*, Vol. 260, April.

National Climate Information Disk, Vol. 1. $50. [National Climate Data Center, User Services, Federal Bldg., Asheville, NC 28801. Phone: 704/271-4800] IBM Compatible. This disk has video animation. It also contains climate data from reporting stations in the U.S. from 1895–1989, sortable by location, time period, and data type.

How to Use the National Climatic Data Center's HomePage

Go to the National Climatic Data Center HomePage (www.ncdc.noaa.gov)
Select Interactive Visualization of Climate Data
Choose Climate Visualization (CLIMVIS)
- Table of Contents
  - Available Data Sets
    - Climate Division Drought Data

You will move to the next screen:
Climate Division Drought Data – Graphing Options
- Display the Period of Record for a Parameter
- Display All Divisions for a State, Year and Parameter
- Display all Parameters for a Division, State and Year
- Display a list of the state-division maps

For example choose Period of Record for a Parameter
The next screen will be the following:
Selection Criteria for Displaying Period of Record
- Select the State
- Select the Division Number (region of the state)
- Select the Parameter (Palmer Drought Severity Index, Precipitation, Temperature)
- Output format
- Form control
- Download Options
  - via OASIS
  - via NCDC Anonymous FTP
- Click on Form Control to create image

Other choices may have different selections, for example, Display all Parameters for a Division, State and Year will ask the user to specify the year desired

There is also First Order Summary of the Day Data
The user can select Display the Period of Record for a Parameter at one station
Select a state and go to next page
Select the Station
Select the Parameter (Daily maximum temperature, Departure from normal temperature, Daily precipitation, Average Daily Wind Speed)
Select the Output Fomat
Select Form Control
Download Options
Allow students to surf within NCDC to see how much information is really available!

Teacher's Note

Organization of a homepage may be updated frequently. Accessing information can take different formats as updating occurs over time.

Visualizing Changes in the Earth System

Whenever people talk about the future they form a mental image of what things will be like. They think about themselves and the things they know about, and in their imagination build a new picture of what they can expect. As we consider the impacts of global warming on the Great Lakes, there are a number of ways of visualizing those changes. Some are very personal ways, some creative and amusing, and some that we see only as clouds in the crystal ball. In this set of activities, students will be led to imagine what the Great Lakes region will be like in years to come.

Activity A: What Great Lakes factors will increase and what will decrease as a result of global warming?

The Earth Systems approach emphasizes connections and interactions. As a pretest/posttest assessment of learning, this activity will show how much growth has occurred in such concepts through use of the materials in this volume. Knowing how natural events affect their lives, students can infer a wide range of impacts of global changes in the Great Lakes.

Earth Systems Understandings

This activity focuses on ESU #4 (interactions). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#1, How will water resources in the Great Lakes region be affected?

Materials

- blank wall, chalkboard, or bulletin board
- 1 card labeled GLOBAL WARMING (white or red)
- 20 cards labeled MORE (light color, such as yellow)
- 20 cards labeled LESS (same color as More cards)
- 35–40 impact cards with things that could change as a result of global warming (contrasting light color, such as green)

OBJECTIVES

After the completion of this activity, students should be able to:

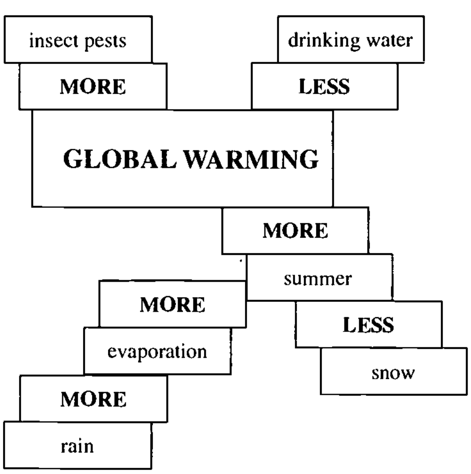
- List and explain many potential impacts with global warming.
- Discuss various interpretations of the possible global warming impacts.

PROCEDURE

1. Gather or construct the materials listed. Before beginning the activity, create impact cards (factors or activities which could be affected by global warming). These impact cards should include both scientific impacts and social impacts (focus on things that can go up and down). Some possible global warming impact cards might include those listed on the next page.

MAKE CARDS FOR THINGS THAT THE GREAT LAKES REGION MIGHT HAVE "MORE OR LESS" OF WITH GLOBAL WARMING, SUCH AS THESE FACTORS

evaporation	income	crop production
snow	extinction	cooperation
drinking water	lake water (lake levels)	fish
severe storms	lakefront property	wetlands
insect pests	rain	tourism
recreation	toxic air pollution	forests
water pollution	electricity	drought
flooding	fear	debate
biological diversity	shipping	summer
winter	disease	air conditioning
ducks	soil moisture	weeds
fertilizer use	pesticide use	dredging of waterways
shoreline development	people	water diversion



2. Make a large card that says **GLOBAL WARMING** and tape it in the center of a blank wall.

   Make a stack for **MORE** cards and a stack for **LESS** cards. Spread the impact cards out over a large table so students can see most of the cards at one time.

3. If used as a pretest, tell students only that global warming is likely to result in lower water levels and changes in the seasons. [As a posttest, this step needs no introduction.]

   Invite students to come forward one table or row at a time and select an impact card which they feel is the direct result of a previously mounted card. They should then select either a **MORE** or a **LESS** card (whichever they think to be correct for the impact that they selected). The student then tapes these to the wall, connecting them with the previously mounted card to indicate that it is the sequence of impact. For example, the first student may decide that GLOBAL WARMING (taped to the wall) leads to MORE INSECT PESTS, or LESS DRINKING WATER. Students must be able to justify the position of the cards they add, and their choice of **MORE** or **LESS** impact.

4. As students use these cards, it will become apparent that there are various interpretations of the impacts. For instance, more weeds and insect pests would probably invade the region, and soil moisture would probably decrease if global warming occurred. However, annual temperatures would be higher and growing seasons longer. The net result could be either more or less crop production. Much would depend on the fertility of northern soils; where and when precipitation falls; and which crops are grown. Have the class discuss all interpretations.

5. To assess student understanding, it may be helpful to have each student select a chain of at least eight cards, diagram them in a portfolio, and give a possible explanation for the links illustrated.

Review Questions

1. List and discuss potential scientific and social factors which may be affected with increased global warming.

2. How can the variety of interpretations of global warming impacts lead to uncertainty among policy makers? How do policy makers deal with such dilemmas?

Extensions and Alternatives

This activity can also be used at various stages of a unit. For instance, it can introduce a new topic and relate it to previous ones or it can be a culminating activity to draw all aspects of a study together. In addition, it would be an interesting evaluation to take a Polaroid photograph of the concept map created at the beginning of a unit and compare it with the map produced at the end. Some teachers use this as a group activity among 4–6 students. Instead of sheets of paper, they use 3x5 cards. This avoids the problem of students having to wait for their turn at the board, and it also results in many different maps that can be compared in group discussion. Groups can prepare a written or oral presentation of their maps, analyzing the thinking about interrelationships that produced the array.

Answers to Review Questions

1. Accept a large variety of answers for this question. Jobs would be created to help develop new crop seeds that could tolerate warmer, dryer conditions. Farmers would need to adjust their crops and farming practices to respond to the changing conditions. Recreation facilities would need to change their structure for the longer summer season, lowered water levels and warmer temperatures. Fishers and manufacturers of fishing gear would need to be flexible because spawning grounds for fish would decrease and new species would become abundant. Companies that use toxic chemicals may need to adjust their procedures because increased temperatures and incidence of severe storms would cause airborne pollutants to travel further. The lowered lake and river levels would also greatly impact the shipping industry because boats would either be unable to pass through certain areas or would be required to carry a lighter load. This would have repercussions on the companies that use this method to transport goods.

2. Because scientists disagree on what the effects of global warming will be and the severity of these effects it is not simple for policy makers to make decisions on related issues. They are forced to make difficult decisions based on differing hypothetical projections. The effects of global warming are also not straight-forward; agriculture, for instance, in some areas may be improved but in other areas it will be damaged. For most changes, there would also be some groups that will come out the winners and others will be the losers. These uncertainties make decision making difficult.

[This activity is adapted from "More or Less," produced by Zero Population Growth.]

Activity B: What will people see on the long walk to the water's edge?

Teacher's Note

In this activity, students listen to the story that asks them to imagine that they have spent a lifetime visiting the Great Lakes; they are then asked to draw pictures of or describe the changes they have noticed in the Lakes during their lifetime.

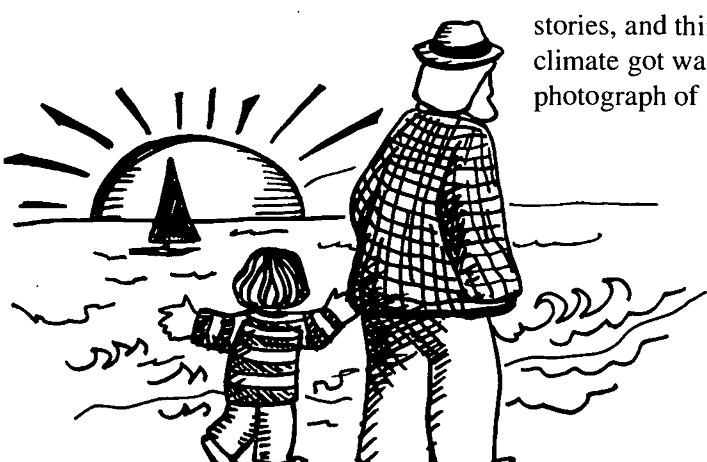
When your grandparents first bought land on the shore of the Great Lakes, it was very beautiful. The forest reached almost to the beach, and ended in some low rolling sand dunes you used to run across with your bare feet flying. From the dunes to the water's edge was barely a skip or two; then your toes could wiggle in the cool water as it swished over the smooth, rounded stones. Along the beach you searched for lucky stones and interesting driftwood to put in the treasure box under your bed.

In the corner of the lot was a low area where some cattails grew, and the water was quiet and warm. Tiny fish swam there, and a green heron came every morning to find a mouthful for breakfast. A big frog once startled you with its lightning leap and a splash into the water when you came too near.

It was great then when the water was so close you could hear it from your open window at night, and the beach seemed only a step away. Whatever your grandparents paid for that place, it was worth it.

So now the old place welcomes you back with your own grandchildren. You've told them stories about how it was; the image is so vivid in their minds as they run toward the beach. Follow them.

On the porch swing that night, your daughter wants to hear what her children saw, and what YOU saw today. Tell her the two stories, and think about how things have changed since the climate got warmer. She might appreciate a picture, your mental photograph of then and now.



Activity C: How do cartoons and comics present environmental issues?

Together, cartoons and comic strips are an important and popular feature of newspapers, and readers often locate them first when reading the newspaper. Most local newspapers devote a page or more daily to comic strips (also known as comics) and several pages in separate Sunday segments. They print cartoons in the editorial section, among other places in the newspaper. Weekly news magazines are also rich sources for cartoons.

Like other sections of newspapers and other aspects of print materials, comics and cartoons can be meaningful educational tools and can become objects of study themselves. Comic strips often feature familiar and beloved characters and can be either single frame or multiple panel (i.e., two to four). They can be totally self–contained or can be part of an ongoing story in a short or continuous sequence. Editorial cartoons are self–contained and offer to the reader some sort of comment on an important and often controversial issue.

The activities that follow examine environmental cartoons and comics as objects to describe and interpret, subjects to compose and create, and as features to classify and place into categories. All are creative exercises that can be used separately or as a larger unit on how information about the environment is communicated.

Earth Systems Understandings

These activities focus on ESU #1, aesthetics, but could also involve all the other understandings, depending on the subject and cartoons chosen. Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

Varies by choice of cartoon.

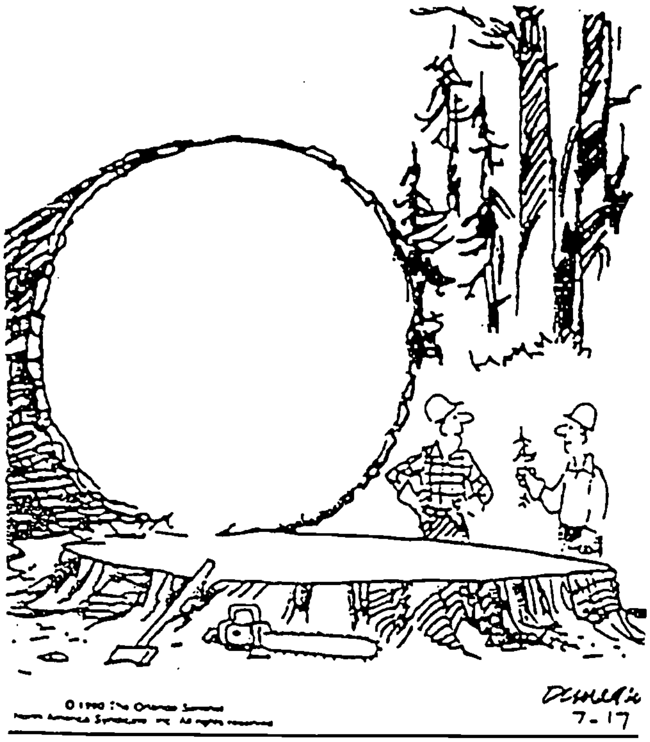
Materials

- Selected environmental editorial cartoons (some are included; substitute others as appropriate)
- Current newspaper and magazine articles for generating ideas
- Pencils, markers, other drawing tools
- Paper, scissors, glue, assorted graphics (for cut–and–paste option)

OBJECTIVES

When students have completed this activity they will be able to:

- Locate and interpret cartoons on environmental issues in newspapers.
- Analyze how cartoons can communicate environmental information in subtle and/or overt ways.



"WELL, THAT'S THAT... DO YOU HAVE THE REPLACEMENT READY?"

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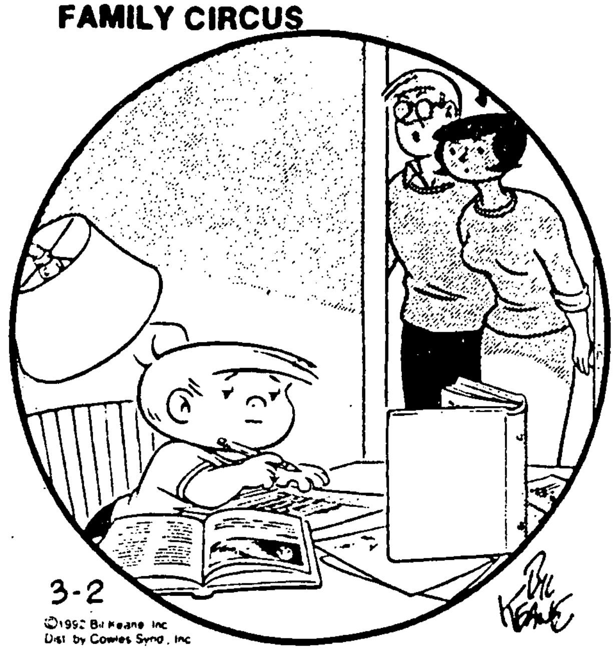
FAMILY CIRCUS



"Isn't seven awfully young to be concerned about global warming?"

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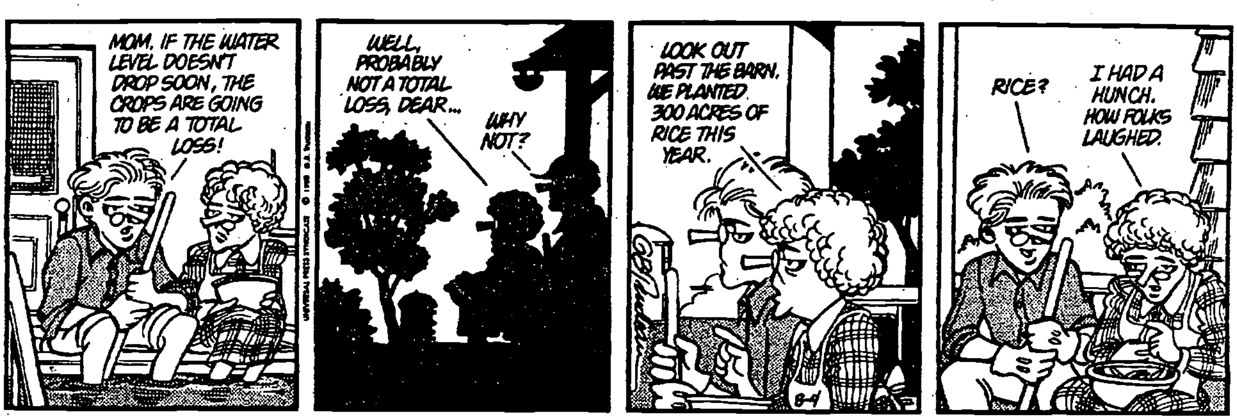
DOONESBURY

By GARRY TRUDEAU



PROCEDURE

Working in small groups or as individuals, students do the following:

1. In a paragraph or two, describe a provided cartoon. What is happening? Where? What has happened before? Who are the main characters? Supporting characters?

2. Using one of the provided cartoons as an example, answer the following questions:

   a. Who or what do the artist's drawings represent? Specify people, symbolic objects, concepts, *metonymical* devices. Metonymical is defined as a figure of speech in which the name of one thing is used in place of that of another associated with it, for example, "White House" when used to mean "President."

   b. What exaggerated features or symbols make clear who or what is represented?

   c. Discuss the language used in the caption. Is there a pun or double meaning? Is there an "ironic" quote?

   d. How does the cartoon comment on an issue currently in the news? Can you find an editorial that verbalizes rather than illustrates the same view on the issue?

3. When the team is finished, trade cartoons with another team. After the new cartoons are analyzed, discuss any differences in interpretation. What is the basis of these differences?

4. Divide a bulletin board into several environmental categories including global warming and other environmental issues in the Great Lakes. Have students search for and select appropriate environmental cartoons and comics from newspapers and other print sources.

Answers

1. Use of satire to illustrate a point. Call attention to aspects of issues. Invite readers' interpretation.
2. Factors such as culture, age, or experience of the audience or cartoonist could result in an audience not fully understanding a cartoon's meaning.
3. Have students brainstorm and discuss ideas.
4. Accept any thoughtful possibilities. Discuss results in class.

Review Questions

1. How have cartoons and comics become an important form of environmental communication?
2. Explain why some cartoons do not relay the artist's intent. Discuss changes that could be made for better understanding of the cartoon.
3. As a cartoonist, you must address air toxins in your weekly comic strip. What factors and examples of those factors (i.e., use of symbols, metonymical devices, exaggeration, and irony) would you incorporate within your cartoon?
4. Develop a short essay on the value (or lack of value) of cartoons as a form of environmental communication. The discussion should include types of audiences impacted, cartoonists' expectations of the audience, and other points that could relate to cartoon impact.

Extension: Creating Cartoons and Comics

With some planning and encouragement, students can create and produce their own cartoons and comic strips on such topical areas as global change, toxins in the Great Lakes, and other important environmental issues. This is a creative as well as motivational activity that has great potential for actively involving the students in their learning and in the overall educational process.

A considerable amount of time will need to be devoted to planning before actually drawing and producing the final product. Students should find an ample source of ideas in the Scenarios. To alleviate any drawing phobia and other artistic anxieties that may exist and surface in some students, stick figures and cut–outs from existing comics are acceptable.

For successful cartooning, follow this detailed ten–step process.

1. *Brainstorming:* Either individually or in a small group, brainstorm different cartoon or comic strip ideas that you may have. Take extensive notes during this process, as small ideas may be expanded at some point, and more complete ideas may be used as is or adapted later.

2. *Storyboarding:* Using the storyboard sheet example, roughly sketch several cartoon or comic strip design layout possibilities. The storyboard is a pre–drawing document that you can use to create rough sketches, outlines, and text ideas and can be used in planning for the final drawing.

COMIC STRIP STORYBOARD FOR ______________________________

Instructions: Use this storyboard for planning both your drawings and accompanying text for your comic strip. Add vertical lines as needed to create a two- to four-panel strip.

Text line, Panel 1:______________________________

Text line, Panel 2:______________________________

Text line, Panel 3:______________________________

Text line, Panel 4:______________________________

3. *Revision:* Before actually doing any drawing, share your ideas for your cartoon or comic strip with others. This can provide feedback and input and can help you to refine your ideas.

4. *Drawing:* Cartoons and comic strips are usually drawn up to 150 percent oversize in pencil, which can then be easily erased to eliminate unwanted features and any possible drawing errors. Complete the drawing phase before the lettering phase.

5. *Lettering:* Next, apply lettering in pencil in legible text. Compare many comic strips and cartoons to see how the lettering appears.

6. *Inking:* Carefully trace the pencil lines with a fine-tipped black marker. Avoid blue ink as it does not reproduce well.

7. *Credit:* Be sure to date the work and give yourself credit somewhere in the illustration. Examine professional artists' signatures and/or initials that are often hidden or carefully placed within an artwork. A title and artist label may also be placed above the final illustration.

8. *Cleanup:* Carefully erase any pencil marks that remain after inking. Carefully and slowly erase any unwanted lines that still exist.

9. *Reduction:* Cartoons and comic strips that have been previously drawn oversize should be reduced 25 percent to 50 percent on a photocopier. Reduction will remove any unwanted erasures and improve the quality and overall appearance of the drawing. By adjusting the contrast control, lines can be made even darker, which is important for final reproduction.

10. *Reproduction:* Duplicate the final cartoon or comic strip at a local printer or on a photocopier. Distribute to an audience in a class booklet for environmental communication.

Teacher Background Information

Barrett, T. 1990. *Criticizing Photographs: An Introduction to Understanding Images.* Mountain View, CA: Mayfield Publishing Co.

An art criticism and art education book that provides extensive information on describing and interpreting photographic and other images.

References

Heitzmann, W.R. 1986. *The Newspaper In the Classroom* Washington, D.C.: National Education Association.

Thomas, J.L. (ed.) 1983. *Cartoons and Comics In the Classroom: A Reference for Teachers and Librarians* Littleton, CO: Libraries Unlimited, Inc.

Biodiversity: Bird Populations

Global change can be monitored by examining numerous environmental parameters. Long-term data covering a large area are helpful to determine if change is occurring on a wide scale over time. Large databases such as the information gathered by the United Nations Environment Program (UNEP) and the International Union for Conservation of Nature and Natural Resources (IUCN) provide a global tracking of environmental changes and trends.

While these international sources provide important and valuable information, they are often removed from students' own environment and personal experience. One large database directly available to students that provides information about areas with which they are likely to be familiar is the annual Christmas Bird Count (CBC). The Christmas Count began in 1900 with 26 locations. Since that time, the count has expanded to 1563 locations in the U.S., Canada, Mexico, and Central and South America. The original counts involved 27 individuals. In 1992, 43,189 individuals participated in the count by observing over 54 million birds. Each count location involves about 30 volunteers spending a 24-hour period doing a winter census of the bird population in a 15-mile-(24.1-km-) diameter area. Each group selects a day from a two-week period, generally in December/ January. The count procedures have remained relatively constant over the years, so the data can be used for comparative purposes.

Birds that overwinter in the northern latitudes have to contend with numerous climatic and environmental conditions.

Birds that overwinter in the northern latitudes have to contend with numerous climatic and environmental conditions, especially temperature fluctuations and food abundance. Dr. Terry Root, at the University of Michigan in Ann Arbor, has been conducting studies on birds that overwinter in North America, particularly in northern areas. She found strong associations between the distribution of 148 land birds and six environmental factors. These included average minimum January temperature, mean length of frost-free period, potential vegetation, mean annual precipitation, average humidity, and elevation. Temperature is the factor of concern in this activity.

As autumn approaches in the middle and high latitudes, the temperature begins to drop, and many birds start to migrate to warmer areas. Some species migrate to tropical regions south of the U.S. border, while others migrate to warmer areas in the southern U.S. Some, however, do remain in the northern, colder areas. These include the cardinal, crow, chickadee, and others. Some of these bird species will remain in the lower regions of the northern latitudes, while other species are located in the higher latitudes.

Activity: Do Christmas Bird Count data reflect trends associated with global change?

In her work, Dr. Terry Root found for the Eastern Phoebe "a striking association" between the average minimum temperature in January and the limit of bird's northern range (Root and Schneider, 1993, p. 263). In this activity the class will investigate the temperature/range limit relationship.

Materials

- Paper and pencils
- Figures and graphs included in the activity

Earth Systems Understandings

This activity applies to ESUs #1 (aesthetics and value), #2 (stewardship), and #7 (careers and hobbies). Refer to the introduction of this book for a detailed explanation.

Scenario Reference

#2, Will Biological Diversity in the Great Lakes Region Suffer?

Answers

1. Local and yearly climatic variations allow the bird species' range to deviate around the isotherm. Therefore, a distributional range may deviate each year. The bird's range is a composite of a number of these yearly deviations.

2. Fragmentation of habitat is not highly variable from year to year, yet fluctuations of bird species over winter are extremely variable. Does this definitely indicate temperature as the main factor influencing bird distribution? **Maybe.**

3. As one proceeds from south to north, (1) the ambient air temperature gets colder, and (2) nights get longer. These factors have a great influence on species' and individuals' capacity to overwinter.

Objectives

When students complete this activity, they should be able to:

- understand how wildlife adapt to variations in the environment.
- relate environmental factors, such as temperature, to bird ranges.
- predict changes in the range of bird populations as a result of global climate change.

Procedure

1. Figure 1 illustrates the influence of temperature on a species' range. Note that the range tends to fluctuate along the isotherm. Why does this fluctuation occur?

2. Is temperature the only factor driving the location of the northern boundary of the phoebe's range? Could variations in vegetation distribution be an influence?

3. Dr. Root decided to examine other temperature-dependent species belonging to the order of *passerines*, including juncos, sparrows, robins, cardinals, and many others. Passerines are generally small-or medium-sized perching songbirds. For the 51 species she selected, their northern range limits were associated with temperature. In fact, two dominant environmental factors were found to influence the winter lifestyle of birds the farther north they traveled. With your team of students, hypothesize what these factors were.

Figure 1. The distribution and abundance of the winter range of the Eastern Phoebe. The northern boundary lies very close to the -4°C isotherm of January minimum temperature (heavy solid line).

(Source: Root and Schneider, 1993.)

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From this information, Dr. Root constructed the following graph (Figure 2) to illustrate the relationship between the various parameters.

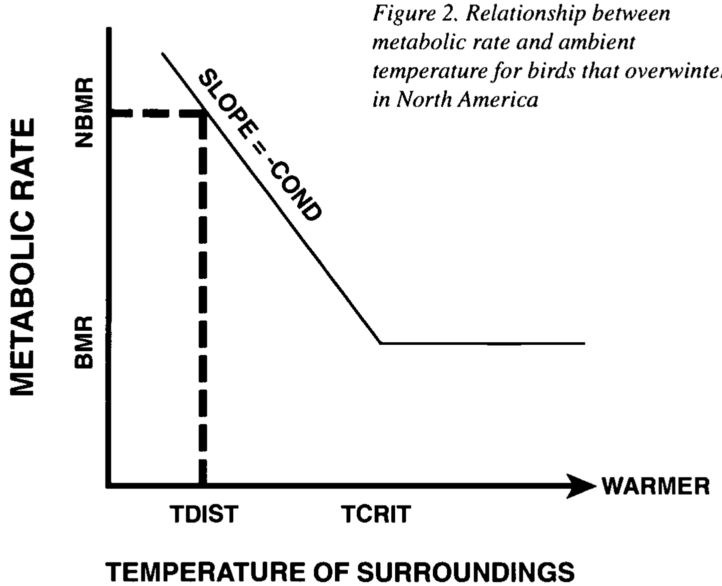

Figure 2. Relationship between metabolic rate and ambient temperature for birds that overwinter in North America

NBMR **Northern Boundary Metabolic Rate** *The highest metabolic rate at which a bird can survive. Above this rate, a bird would not have enough energy reserves to maintain its body heat through the night.*

BMR **Basal Metabolic Rate (Resting Rate)** *Birds can increase this in order to stay warm (the slope of the line reflects this increase as the temperature gets colder).*

TDIST *Temperature at the edge of distribution range. The coldest temperature a species can tolerate.*

TCRIT *Temperature at which a species must increase its metabolic rate in order to keep warm.*

Source: Root and Schneider, 1993.
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4. The Basal Metabolic Rate of the bird is the rate at which it is not performing any function except staying alive (e.g., it is asleep, not cold, not hot, not digesting food). The Northern Boundary Metabolic Rate is the bird's metabolic rate at the northern edge of its range. Figure 2 indicates that the bird's metabolic rate increases as the temperature drops below TCRIT. How would the metabolic rate of an individual in Florida compare to an individual in Michigan in the wintertime?

5. By examining this information from several species, Dr. Root found that the NBMR tended to be an average of 2.5 times the BMR. This has become known as the 2.5 Rule.* But what controls this rule? Various environmental factors could have an influence. What happens to the winter environmental conditions as a bird travels from South to North?

6. On a normal day, passerines accumulate body fat to about 11 percent of their total mass during each day. The following morning, little fat remains. Why?

4. As a species moves farther away from the average temperature of its range toward the northern edge, its metabolic rate increases (slope of line). This is a result of shivering, which generates heat. The survival mechanism of shivering requires energy that the bird gets by burning body fat. The metabolic rate of an individual bird in Michigan would be higher than that of an invidivual in Florida where it is warmer.

5. Two main things happen as a bird travels north during the winter: the ambient temperature gets colder, and the nights get longer.

* The 2.5 Rule was proposed by Jared Diamond in 1988 in an article in *Nature*.

6. To survive the low night temperatures, the bird must shiver. This action requires energy that is obtained from the bird's fat reserves.

Dr. Root concluded that the amount of fat lost over one night must fuel the mechanism for survival.

7. Accumulation of fat depends on various factors. What do you think are the most important of these? (Consider how people accumulate fat!)

To examine the issue of fat and its influence on bird distribution in winter, Dr. Root decided to sample cardinals on a north-south axis and determine if indeed birds in the northern latitudes did have less body fat in the morning. Figure 3 shows the results of this sampling on a south/north transect from Alabama, through Tennessee, Indiana, and Michigan. Estimates are for the amount of fat still present just after dawn.

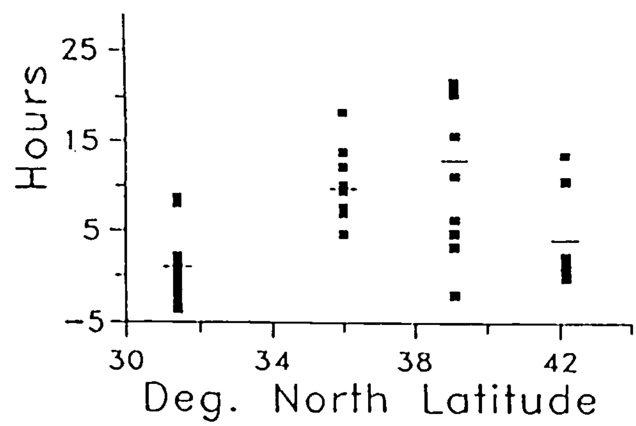

Figure 3. Hours of metabolism that can be fueled by body fat of Northern Cardinals sampled at different latitudes. Birds were sampled in the morning at each location. The average length of time the birds couulld survive indicated with a line (Source: Root, 1991). Reproduced from the book Acta XIX Congressus Internationalis Ornithological, *under the supervision of Henri Ouellet, 1991.*

8. How many hours (mean) of metabolism after waking do the birds possess in body fat for each of the states? Have students locate the various states on a map. What type of weather conditions dominate these states in winter?

9. Consider climatic conditions and the hours of metabolism remaining for cardinals in the morning at each latitude.

7. Some factors could be ambient temperature, foraging time, type and availability of food source, and level of activity.

8. Alabama = 1 hour, Tennessee = 10, Indiana = 13 hours, Michigan = 3 hours. Students can practice their geography skills by locating each state on the map and noting the degrees change in latitude as one travels north to south. The class should consult library resources for additional information on winter conditions for each state.

9. While the cardinals in Alabama have the lowest number of hours of metabolism remaining, winter conditions in Alabama allow the birds to locate food easily. They still need to feed soon after waking, although weather conditions are unlikely to hamper their search.

   In Tennessee and Indiana, winter storms can have a large impact on bird populations. Ice storms and freezing rain can prevent birds from finding food. However, with 14 hours of metabolism in reserve, cardinals should be able to withstand the worst of storms. In fact, present results suggest that some could go without food for up to 2 days before dying. However, additional research is required before this can be stated definitively.

   Cardinals in Michigan have a difficult existence. Winters are harsh and long, with severe snow storms that may last many days. The Michigan birds only have 3 hours of metabolism remaining by morning. Therefore, immediately at dawn, Michigan cardinals must begin foraging if they are to survive.

Imagine what the cardinal's day is like. How can the climate conditions in winter affect the cardinals living in each state?

10. What impact could birdfeeders have on cardinals in each of these states?

10. These could have the greatest impact on survival of birds in Michigan. If a cardinal can get to a feeder in time, it should be able to replenish its fat reserves fairly quickly.

It would seem from this information that foraging time (length of day) and ambient air temperature will both play a significant role in the survival and distributional patterns of birds.

11. From what we know of the possible changes that will accompany global warming, which of the two factors is likely to have the greater effect on the bird populations of North America? Examine the CBC of an area of the continent where climate may be similar to the type of climate predicted as a result of global warming for the area where your school is located. What kinds of birds can you expect to move into your area? What factors would determine whether they would survive there?

12. Consider the possible impacts of the last two winters on individual cardinals and other species and their populations.

. . . foraging time (length of day) and ambient air temperature will both play a significant role in the survival and distributional patterns of birds.

Review Questions

1. What factors influence the overwintering distribution of birds? How was the 2.5 Rule determined? How do birds stay warm and remain alive during the night when the temperature drops? What consequence does this force on the birds?

2. Would the birds in the 30°N latitude area have fewer or more hours of metabolism remaining in the morning in comparison to birds at 40°N?

3. Develop a concept map illustrating the Earth Systems interactions in this activity. Include all the Earth Subsystems and use connection lines and verbs to explain the interactions.

4. Scientists involved with global change use proxy data, such as the CBC, to try to predict future changes in population numbers and dynamics resulting from possible climatic alterations. From the evidence in this activity, do you think it is possible to use CBC data to predict the influence of possible climatic changes on bird populations and populations of other organisms? Write a paper describing your position on the use of such datasets to predict change.

CBC data can be obtained by contacting:
The National Audubon Society
700 Broadway
New York, NY 10003
Phone: 212/979-3000
Fax: 212/353-0508
The following can be purchased.
The National Audubon Society Field Notes, CBC Issue. This contains results of all previous Christmas Bird Counts.

For disks of CBC data or analysis of population changes, contact:
National Biological Service
301/497-5819
HomePage:
http://www.im.nbs.gov/im.html

EXTENSIONS

1. What happens to the birds that migrate South for the winter? Investigate a species that uses this mechanism to overcome falling temperature. What impact would habitat fragmentation have on such a species? (Read the *World Book Science* Year 1994 article, "The Case of the Missing Songbirds," and the *Audubon* article, "Mystery of the Missing Migrants," for good discussions of this topic.)

2. We intuitively understand that weather and climate vary with latitude, but there are datasets that document such differences and perhaps hold a few surprises. Use the NCDC climate data (via Internet, e-mail,or CD-ROM) for winter in Michigan, Alabama, Tennessee, and Indiana. Graph relevant temperature and precipitation data to help understand what conditions birds must survive. Regional temperature data can also be downloaded from Trends '93, CDIAC's ftp, for example the Great Lakes, South Coastal Plain, and Eastern Prairies regions, pp. 717, 721, and 723. The National Climatic Data Center's homepage on the World Wide Web provides precipitation data by reporting site.

3. From your library or the local chapter of the Audubon Society, have students obtain the fourth issue of each year's *American Birds* for the last twenty years for the count location nearest your school. The students can create spreadsheets either manually or on computer for the location. Then they can graph trends either for an individual species or a group of species over that time period.

Carbon Dioxide Information
Analysis Center
Trends '93. A compendium of data on global change.

Regional temperature data can be downloaded in the following manner:

ftp cdiac.esd.ornl.gov
Name: anonymous
Password: YOU@your e-mail address
Guest login ok, access restrictions apply.
ftp>cd/pub/trends93
ftp>dir
ftp>cd temp
ftp>get glakes721
ftp>quit
ftp>Goodbye

Precipitation Data from the World Wide Web:
http://www.ncdc.noaa.gov
Click the Online Data Access Button
Choose Anonymous FTP Archive – U.S. Monthly Precipitation for Cooperative and NWS sites
Choose a reporting site within a state
With the cursor, highlight the data
Copy it to a word processing file.
Transfer data to a spreadsheet format, parse the data and place the decimal where appropriate.
The data are now ready to be graphed for a particular month or season.

To request searches by state for temperature and precipitation data, contact the National Climatic Data Center.
By e-mail: ORDERS@ncdc.noaa.gov

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Root, Terry L. and Stephen H. Schneider. 1993. Can large-scale climatic models be linked with multiscale ecological studies? *Conservation Biology* 7(2): 256-270.

Walter, Eugene J. 1993. The case of the missing songbirds. *1994 Science Year. The World Book Annual Science Supplement.* Chicago: World Book, Inc. 29-43.

Willie, Chris. 1990. Mystery of the missing migrants. *Audubon.* May. 92(3): 80-85.

Biodiversity: Forest Ecosystems

Scientists today are concerned that the world's climate is changing at an unprecedented rate because of human activities. If global climate change occurs as predicted, the northern latitudes could experience warmer climates than presently exist, resulting in a northward displacement of ecological zones. This will have a dramatic effect on some trees, such as the sugar maple population found in the Great Lakes region.

Forest composition is known to change over time. One way that these changes are studied is by looking back through time (to as early as the last Ice Age) and analyzing preserved pollen samples. More recent forest changes, occurring within the past several hundred years, can be identified by studying old recordings that were made following major events such as fires and clear-cutting. Indirect methods, such as historical records of travelers' journals and surveyors' notes, are also used to compare the forests of the past to those of today. These forest changes provide clues as to how forests evolve over time and how global climate change might affect the forests of the Great Lakes region.

When global change occurs slowly, plants adapt and/or migrate to other more favorable geographic locations. When global climate change occurs rapidly, plants cannot adapt or migrate quickly enough and consequently die out. Several projections have been made about the sugar maple (*Acer saccharum*) and where it will migrate during global climate change. Figure 1 shows the present-day maple forest and two projection models of where their range might be under warmer climate conditions. Figure 2 shows how quickly various tree species have migrated over the course of several years. While studies have been done to predict patterns of migration, little has been done to ascertain what species will become dominant in the Great Lakes region when the maples are gone.

Present

Source: Zabinski and Davis (1989)

General Circulation Models

Goddard Institute for Space Studies (GISS) 2 x CO_2

Geophysical Fluid Dynamics Laboratory (GFDL) 2 x CO_2

Figure 1. Changes that may occur in the range of sugar maple trees if atmospheric CO_2 were to double

Sugar maples have been important to people for a long time. The wood of maple trees is stiff and heavy. It is often used to make furniture and musical instruments because of its beautiful grain. Early settlers and Native Americans in the Eastern United States depended on maple trees to help sustain them through the winters. They could turn the sap into maple sugar to be used as an important source of energy throughout the cold season.

The maple season is dependent on temperature. When the nights are below freezing and the days are above freezing, the sap flows. This happens in the fall and the spring as the seasons change. The sap of sugar maple trees is approximately 2 percent sugar, and it takes between 30-55 gallons of sap to make one gallon of syrup depending on the density of the sap. Imagine how big a 50-gallon drum is. That's a lot of sap! One tree can usually produce more than 50 gallons of sap in a season (usually between 10-15 gallons per tap hole, though some holes have been known to give 40 gallons in an unusually long season).

Humans are not the only "animals" to enjoy maple sap. Many birds, such as sapsuckers, leave their telltale marks on the side of maple trees.

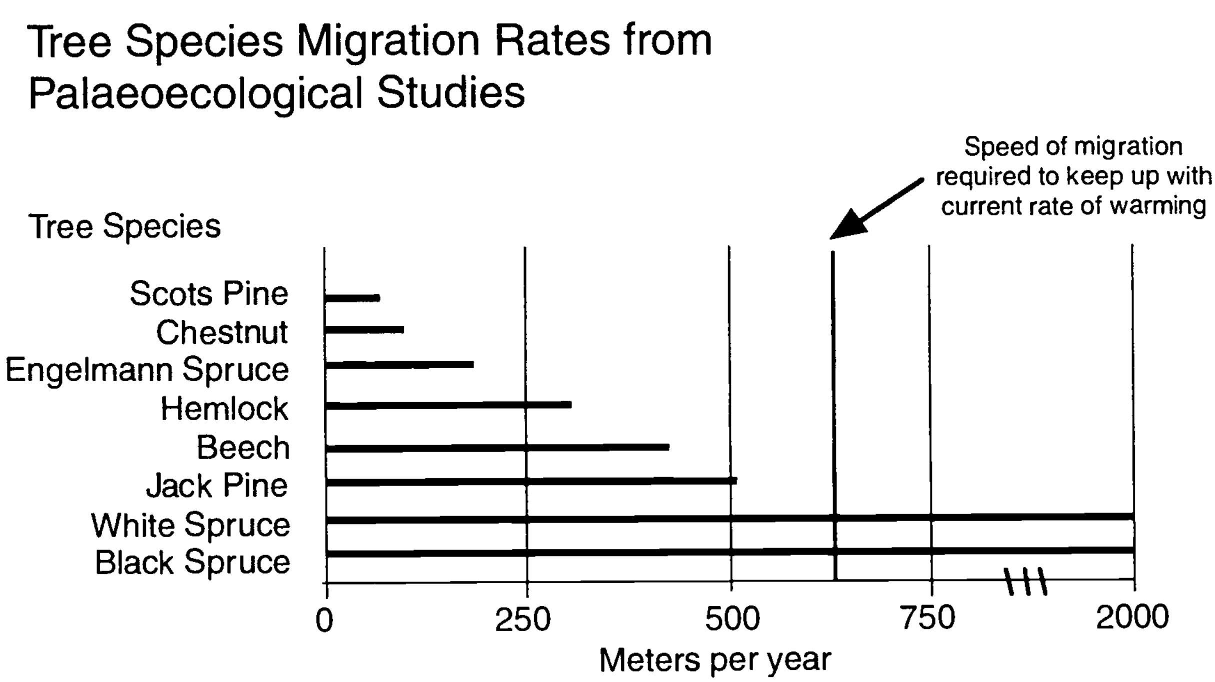

Figure 2: Tree Species Migration Rates from Paleoecological Studies
Reprinted by permission of the World Wildlife Fund, 1995, Conservation Issue, Vol. 2 No. 1, February.

Activity A: After the maples, then what?

This activity is patterned after the 1953 study done by Catherine Keever, an ecologist with exceptional foresight, when she studied the dominant species remaining after the chestnut blight removed the chestnut trees from the oak-chestnut forests of the Blue Ridge Mountains. Students will go out into a maple forest and, using Catherine Keever's methods, will predict the possible dominant species if the maple trees are removed.

Objectives

At the completion of this activity, the student should be able to:

- Identify a sugar maple (*Acer saccharum*) tree and associated species of a maple forest.
- Locate on a map the general area where sugar maples grow today and where they may migrate with global warming.
- Explain one way in which ecological studies are done to predict future dominant species in an ecosystem.
- Make a prediction as to the possible dominant species if maples are removed from the forest.

Earth Systems Understandings

This activity focuses on ESU 3 (science methods and technology), 4 (interactions), and 5 (change through time). In addition, Extensions address ESU 1 (aesthetics and value), 2 (stewardship), and 7 (careers and hobbies). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#10, How will forests in the Great Lakes region be affected?

Procedure

In this activity, students will identify and count trees in three different size plots, each nested within each other. Since maple trees are the main concern of this activity, it is important that students can identify them. One way to help with tree recognition is to bring in twigs from several types of trees and have the students examine the differences and pick out the maples. Some distinguishing characteristics of maples twigs are their buds, bud scars, and opposite branching.

1. Using stakes and twine, students mark off three plots in a woods containing maple trees. See Figure 4 for measurements. The two smaller plots do not have to be in the exact center of the larger one, but they should be nested within one another inside the 10 m x 10 m plot.

Materials

- a forest (or woods of any size) with maple trees and associated species
- 12 stakes at least 60 cm long and pointed at one end
- rope or twine, about 70 m
- several meter sticks or rope cut to specific lengths for measuring the height of trees
- paper, pencil, and clipboard
- graph paper or prepared grid sheets
- tree and plant field guides for identification

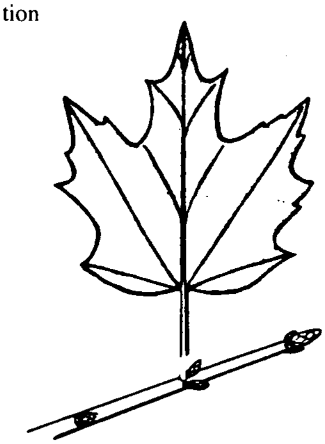

Figure 3. Sugar maple twig and leaf.

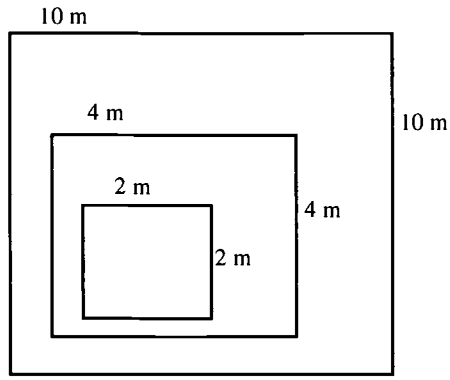

Figure 4. Nested study plots within a maple forest

2. In each plot, the students will inventory different size trees. Each tree of the specified height must be identified and plotted on a grid sheet. In the 10 m x 10 m plot, the canopy and understory trees 3 m or taller are identified and recorded. In the 4 m x 4 m plot, the trees between 1 m and 2 m tall are identified and recorded, and in the smallest plot (2 m x 2 m), any trees 30 cm and shorter are identified and recorded. Figure 5 illustrates one method of recording.

3. After all the trees have been identified and recorded in their successive plots, have the students compare their data from each plot for similar species. Overhead transparencies work well for this step.

4. If any one species is found in all plots and all sizes, it is possible that it may become a dominant species of the maple forest. After comparing all of your data, what prediction can your class make for the dominant species of your maple forest if maple trees would die out or migrate northward?

Review Questions

1. Why are people concerned that sugar maples and other tree species will be lost with global warming?
2. How and why do forests get displaced (migrate)?
3. Predict the impact of maple "migration" on other trees and on animal and human communities.
4. What characteristics will "new dominant trees" have compared to those which were displaced?
5. Will global warming damage the overall health of maple forests?

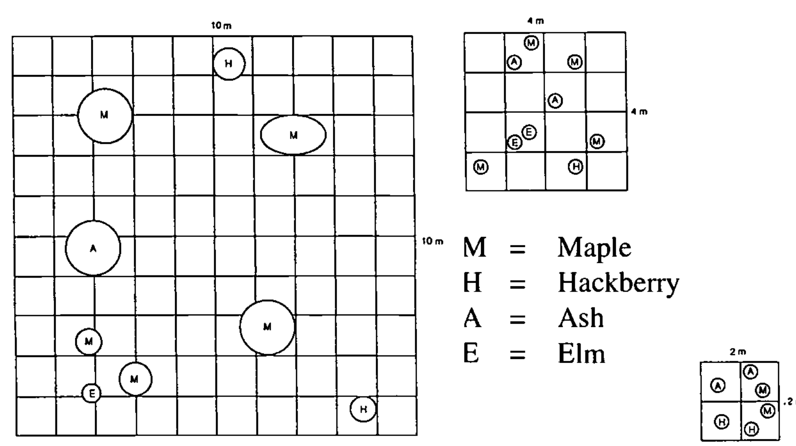

Figure 5. Sample drawing of the three plot–study grid

Answers to Review Questions

1. Have students brainstorm and discuss. Responses should include wildlife habitat needs, human foods, lumber, and ecological factors of the forests.

2. If climate change occurs, the plants will survive only in more favorable geographic locations. That is, as their seeds are disseminated, only those that fall in the new favorable habitats will survive. This change happens slowly. For an excellent activity about how trees migrate, see *Activities for the Changing Earth System* (1993) from the Earth Systems Education Program, The Ohio State University.

3. Other tree species that rely on the maple for shading and protection may be lost. Some tree species that can tolerate the new environmental conditions better than the maples will become the dominant species. Any animals or humans that rely on maples must adjust.

4. The "new dominant trees" will have to be more tolerant to warmer climate conditions, and possibly a different seasonal pattern of moisture. Note: there is no guarantee that some of these trees are already growing in the sample plot, as they may move in from other areas.

5. The health of a forest is vital to the life of the whole ecosystem. Global warming is likely to change the nature of the present maple forests significantly. It may take a century or more before a stable new forest ecosystem emerges.

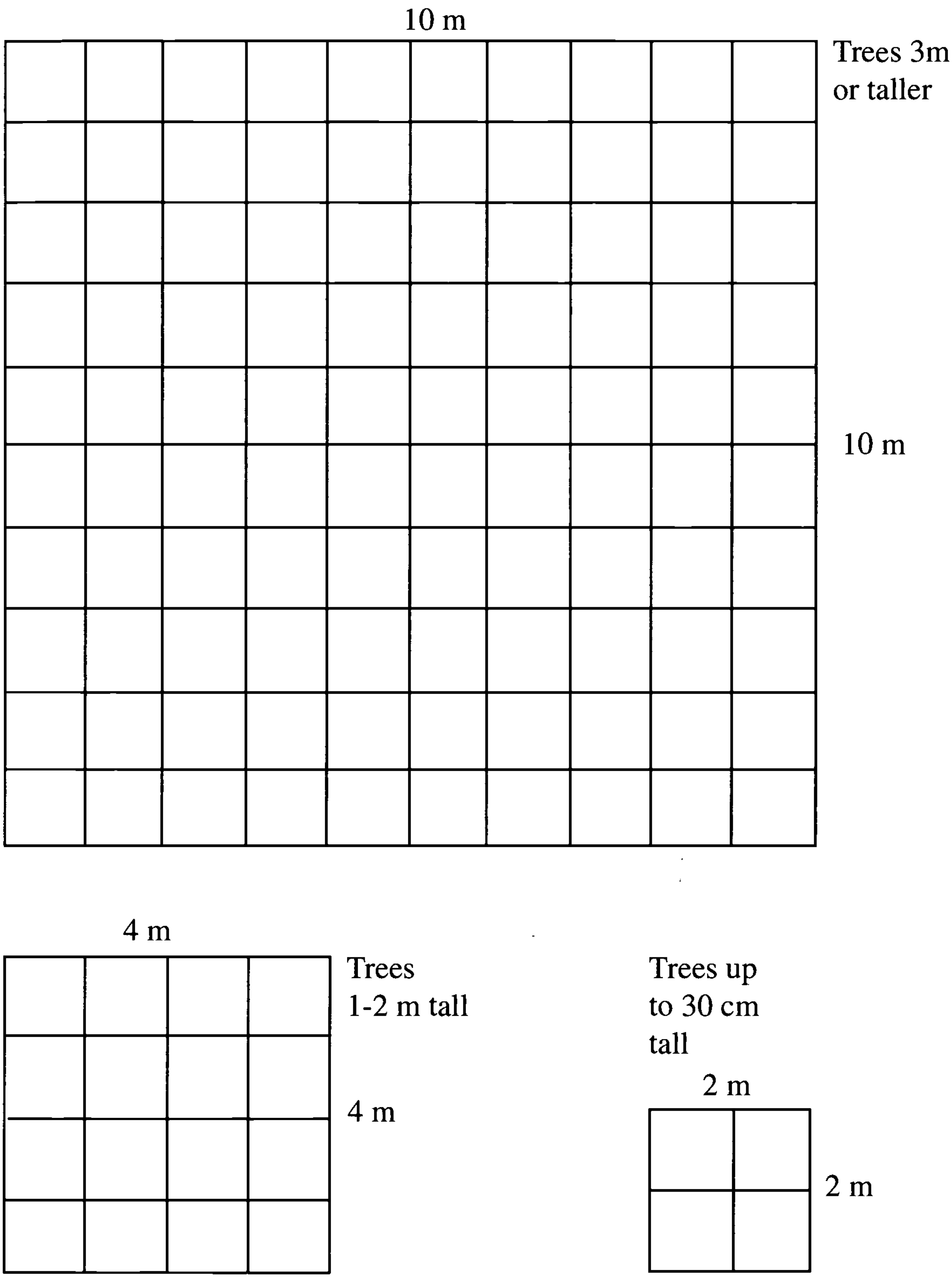

Figure 6. Grids for recording tree species in the three plot sizes

Extensions

1. In groups of four to six students, discuss how human activities are impacting maple forests. Brainstorm how these impacts can be minimized.

2. Do research on hardwood forests, particularly maple forests, to learn how natural factors (soil, precipitation, humidity, etc.) affect their location and growth. How do you think global climate change might affect these factors, which will in turn affect the forests?

3. Discuss how humans use maple trees and the products we get from them. How might your life change if there were no more maples? Describe substitutes that you might use in place of maple products.

4. Imagine that you are the oldest person in a community, having lived nearly 100 years. The school children contact you and ask you about the maple forest that they have never seen. Write a letter to their class, or draw a picture, describing a maple forest, telling them of your recollections and experiences in a maple forest of your youth.

5. Sketch or paint your impression of the maple forest where you did this plot study, or draw a single maple tree to capture its character.

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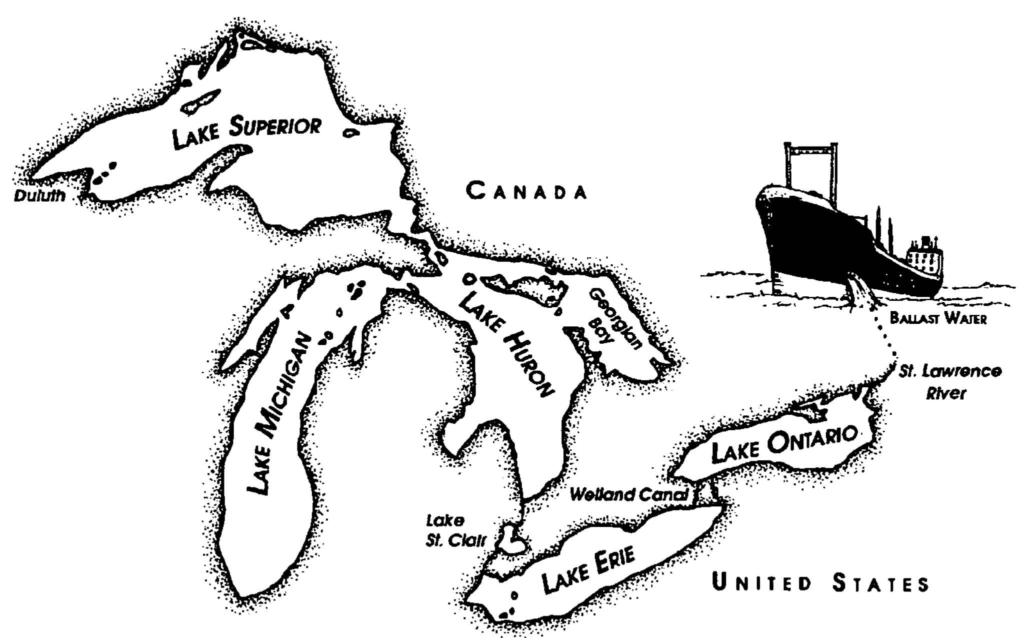
Biodiversity: Nonindigenous Species

Since the early 1800s, some 139 species of aquatic plants, algae, fish, worms, mollusks, and other organisms have invaded the Great Lakes. Likewise, some North American species such as the green sunfish (*Lepomis cyanellus Rafinesque*) have migrated eastward and have become pests in Europe. Biologists worry about these intrusions, because each new species in the Great Lakes alters the region's ecosystem. Any environment has a fixed amount of energy that must be divided among all the species present. When a foreign (exotic) species invades an ecosystem, it often has no enemies. This allows an invader to increase rapidly, displacing native organisms by filling their niche. This change allows the once biodiversified region to lose some of its genetic diversity.

It is estimated that 24 of the 175 species of fish in the Great Lakes are nonnative species that were introduced accidentally or intentionally. Eighty–six invader species are plants, although plants have received less attention as invaders. How these invaders get into the region is variable, but many have been shipped in unintentionally.

When ships are not loaded with cargo, they take on ballast to balance and stabilize them as they travel. The use of water as a ballast material has replaced the use of sand and stones. Ballast tanks are filled with water from the harbor where ships are loaded, and then dumped, along with any aquatic organisms present, when ships reach their destination. It is estimated that in the history of the Great Lakes, 34 percent of the invader species entered in solid ballast and 56 percent through ballast water. As shipping times between continents becomes shorter, the threat of introducing live exotics becomes greater.

The United States and Canada have requested that all ships entering the Great Lakes discharge their water ballast while still in the ocean, replacing it with salt water in order to reduce the introduction of new exotic species. About 90 percent of the ships currently comply with the request.



Activity: What do scientists know about invader species of the Great Lakes and the effects that global climate change will have on them?

Earth System Understanding

This activity focuses on ESU 3, 4, and 5. In addition, Extensions address ESU 1, 2, 6, and 7. Refer to the Framework for ESE for a full description of each understanding.

Scenario Reference

#2, Will biological diversity in the Great Lakes region suffer?

Materials

For each group of 3–4 students:

- Copies of the included information cards. Each of the four card categories (invader picture, introduction, ecosystem impact, and climate change) should be copied onto a different color card stock paper
- Answer sheet

Invader Species in this Activity

Zebra Mussel
(*Dreissena polymorpha*)
Sea Lamprey
(*Petromyzon marinus*)
Spiny Water Flea
(*Bythotrephes cedarstromi*)
River Ruffe
(*Gymnocephalus cernuus*)
Alewife
(*Alosa pseudoharenges*)
White Perch
(*Monrone americana*)
Purple Loosestrife
(*Lythrum salicaria*)
European Water Milfoil
(*Myriophyllum spicatum*)

Objectives

At the completion of this activity the student should be able to:

- Name and visually recognize some invader (*nonindigenous*) species of the Great Lakes.
- Locate on a world map the origins of the Great Lakes invader species.
- Explain the ways in which invader species are introduced into the Great Lakes.
- Explain the impacts of invader species on the Great Lakes ecosystem.
- Analyze the impacts of global climate change on invader species of the Great Lakes.

Procedure

1. Copy the included cards (one complete 4-color set of 32 for each group) and cut them apart.

2. Divide class into groups of three to four people each. Give each group a complete set of shuffled cards. (If there are eight groups, each group will be able to take a separate invader to report on at the conclusion of the activity.)

3. Beginning with the picture of the invader, each group should match the cards to determine which introduction, ecosystem impact, and global change card goes with each invader. For each picture, there should be one matching card of each other color.

4. When group members agree that they have matched the cards to the best of their ability, they may check their answers on the answer sheets.

5. Have each group of students select an invader to present to the class; the students could construct a poster on the invader, develop a fact sheet, or create a skit to explain their invader. The impact of the invader on human affairs should be included.

Extensions

1. Do research on controls that have been tried on various invader species and report on their successes or failures. Brainstorm a creative way to control one of the invaders.

2. Draw a humorous cartoon depicting the problem of invader species. (Example: A zebra mussel looking for a place to attach on an already-overcrowded lake bottom, a white perch nudging out a yellow perch, purple loosestrife choking other plants, etc.)

Review Questions

1. Why should people be concerned about nonindigenous species?

2. How can the transfer of invader species be controlled or stopped in the Great Lakes or elsewhere in the world? Draft a piece of legislation that your group thinks could be enacted to stop exotic species from invading the Great Lakes.

3. Explain what effects global warming may have on any of the invaders discussed — which species will benefit by the change and which will be negatively impacted?

4. Identify as many Great Lakes jobs as possible that are impacted by invader species. (Some impacts may be positive, that is, new jobs may have been created by the newcomers.)

Answers to Review Questions

1. Invading species threaten to change present ecosystems, often in unpredictable ways. Because invaders frequently do not have predators, they often have the ability to disrupt the existing ecological balance and dominate an area. Consider the effects of European humans after their introduction to North America. How many other species have humans displaced?

2. Bilge water is critical to the spread of invaders. Have students brainstorm different ways that invaders can be introduced and possible methods for preventing their spread.

3. Refer to Global Climate Change cards.

4. Increased numbers of researchers are needed to study the potential impact and spread of the invaders. There could be new public water systems and industry jobs to keep pipes clean. Fishers will be affected because the type and quality of catch (fish size and health) will be different. Beach cleaners would be needed to get rid of dead fish, and boat cleaners will be in great demand to protect boats from invaders (potentially by developing and applying special toxic paints that will prevent zebra mussels in particular from adhering to boat hulls). Recreation facilities will most likely also experience some increased business because of the added water clarity that zebra mussels cause by filtering water, but may also lose some business because of decreased fishing opportunities. Park systems and gardeners must be concerned, because invader species will compete with the native vegetation and wildlife.

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INVADER #1

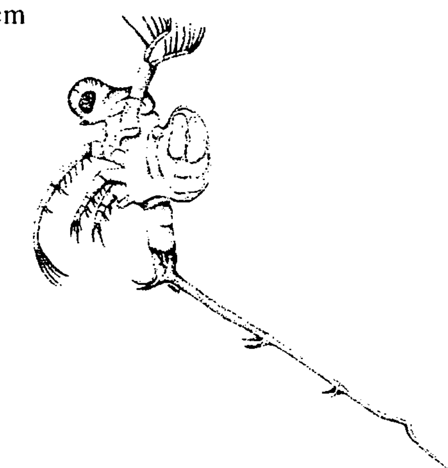
Zebra Mussel (*Dreissena polymorpha*)
Adult size: 1-4 cm long

INVADER #2

Sea Lamprey *(Petromyzon marinus)*
Adult size: 3 feet (91 cm)

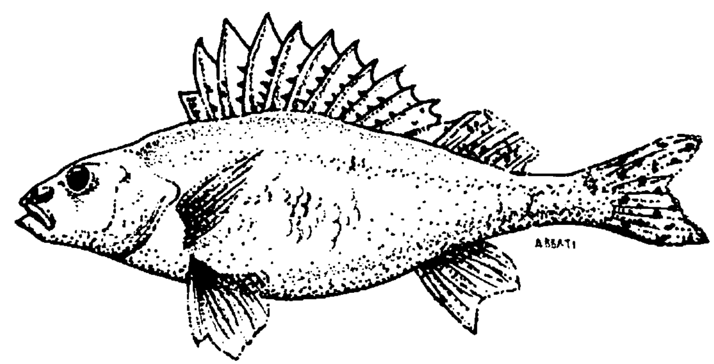
INVADER #3

Spindy Water Flea (*Bythotrephes cedarstromi*)
Adult size: 1 cm



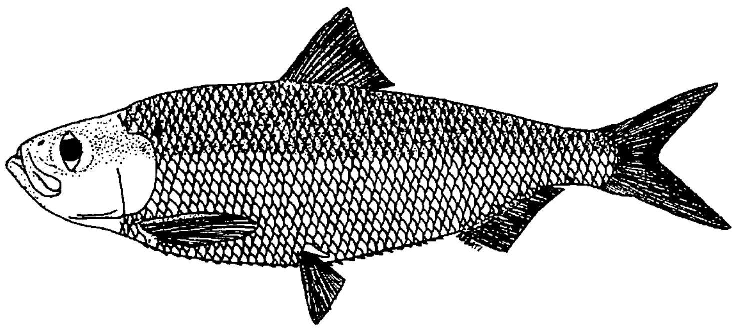
INVADER #4

River Ruffe *(Gymncephalus cernuus)*
Adult Size: usually less then 15 cm long



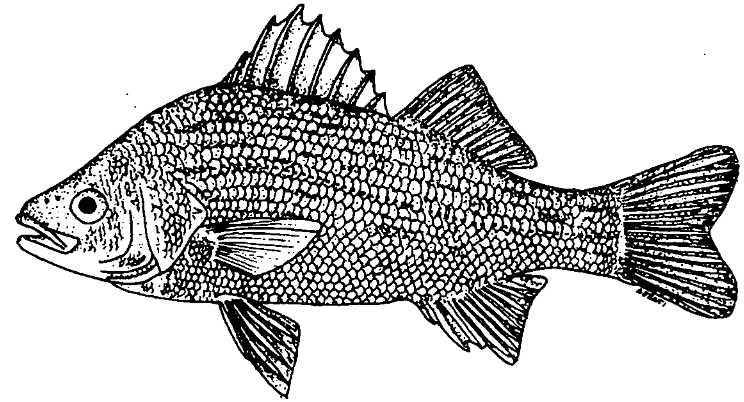
INVADER #5

Alewife (*Alosa pseudoharengus*)
Adult size: 3 cm



INVADER #6

White Perch (*Monrone americana*)
Adult size: 30 cm (20 cm is more common)



INVADER #7

Purple Loosestrife (*Lythrum salicaria*)
Adult height: .5 to 2 meters tall

94

INVADER #8

Eurasian Water Milfoil (*Myriophyllum spicatum*)
Leaflet is actual size

95

INTRODUCTION

Originally it came from the Caspian Sea region of Poland, Bulgaria, and Russia. Canals built during the early 1800s allowed it to spread throughout Europe. By 1830 it had invaded Britain. First introduction into the Great Lakes was about 1985, when one or more transoceanic ships discharged ballast water into Lake St. Clair. Freshwater ballast from a European port likely contained larvae and possible yearlings. Being a temperate, freshwater species, it found the plankton–rich Lake St. Clair to its liking.

INTRODUCTION

Arriving from the freshwater and brackish water in northern Europe, this invader was discovered in Lake Superior in 1986. It is assumed that it "hitchhiked" in ballast waters from Europe and Asia. In 5 years, its population reached 1.8 million adults, making it the most abundant fish in the Duluth harbor. This bottom feeder can reproduce in its first year and the females may lay 13,000 to 200,000 eggs per season.

INTRODUCTION:

Originally, it came from the Atlantic Ocean, the St. Lawrence, and Hudson Rivers, and their tributaries for spawning, and possibly Lake Ontario. It swam from Lake Ontario into Lake Erie through the Erie and Welland Canals, gaining entry into the upper Great Lakes by attaching to hulls of boats.

96

INTRODUCTION

A native of northern Europe, it made its way into Lake Huron in 1984 and was present in all Great Lakes by 1987. It is believed to have been brought over in fresh water or mud in ballast water of European freighters from Eastern Baltic Ports, as studies show that the Great Lakes species closely resembles the species in the ports of Finland and St. Petersburg (the former Leningrad).

97

INTRODUCTION

This species was intentionally imported from Northern Europe over 100 years ago, because its hardiness and beautiful flowers were popular with landscapers, florists, and gardeners.

INTRODUCTION

It came from Europe, Asia and North Africa and was introduced into North America as an aquarium plant. It has since spread to 37 states and 3 Canadian provinces.

INTRODUCTION

Coming from the salty Atlantic Coast, this invader migrated through water routes, including canals in New York State and the St. Lawrence River. It swam into the upper Great Lakes through the Welland and/or Erie barge canal before 1931.

98

INTRODUCTION

From saltwater areas of the Atlantic Coast, this invader moved up the Hudson River and via various canal systems into Lake Ontario and Lake Erie.

99

ECOSYSTEM IMPACT

This is a large plankton form that eats the smaller plankton, thereby competing with small fish for their food source and affecting their survival and growth rates. Its spiny tail prevents young fish from swallowing it, thus removing it from the food chain. It is an invader species so new that it may take years to determine its total impact.

ECOSYSTEM IMPACT

Only about 8 inches long, this perch-like fish has no value as a sport or food fish. It is less temperature-dependent than perch and tolerates more polluted areas. It also can find hidden prey in soft sediments more efficiently than its competitors. This fish is not preferred by predators because of its spiny fins. It displaces sport and food fish, especially yellow perch and walleye, yet is not readily consumed in the food web. This invader made up 90 percent of the fish population in the Scottish lake, Lock Lomond, only 9 years after it was introduced.

ECOSYSTEM IMPACT

It is called "the beautiful killer," because its dense roots choke waterways as it competes with other vegetation. It spreads quickly, crowding out valuable plants that provide food for migrating waterfowl, and destroys habitat for almost all other forms of wetland life.

ECOSYSTEM IMPACT

Forms thick mats that choke out native aquatic vegetation. It disrupts all forms of water recreation—boating, swimming, and fishing.

ECOSYSTEM IMPACT

It destroys valuable fish, especially lake trout, by attaching with its sucker-like mouth to suck out the blood and body tissues. It upsets the ecological balance by removing top predators, allowing for explosion of the populations of smaller fish such as alewives. It had great economic impact on the commercial fishing industry of the Great Lakes during the 1950s.

ECOSYSTEM IMPACT

Suspected to be partially responsible for the decline of Lake Erie's yellow perch because of competition.

ECOSYSTEM IMPACT

It filters the plankton from the water, binding what it doesn't use into pellets that cannot be used by other plankton-feeding organisms. It accumulates on objects such as boat hulls and underwater pipes, clogging valves of both industrial and municipal water intake sources.

102

ECOSYSTEM IMPACT

Large numbers die off in spring and summer because of electrolyte imbalance from living in fresh water. These die-offs clog municipal and industrial intake pipes and foul beaches. In 1967 bulldozers had to remove 50,000 tons of the rotting fish. The sea lamprey enabled this invader to thrive in Lake Erie by killing lake trout and other fish at the top of the aquatic food chain. After the sea lamprey arrived, this invader proliferated. Between 1960 and 1966, for example, they went from representing 8 percent to 80 percent of Lake Michigan's fish by weight. Presently this invader is food for larger game fish.

103

Effects of Global Climate Change

Warmer stream temperatures create a more favorable environment for this parasitic organism, enabling it to spawn successfully at more locations throughout the Great Lakes Basin. This could result in an increase in population, that may further upset the ecological balance of the Great Lakes.

Effects of Global Climate Change

This plant thrives as waters warm each summer, increasing in volume in relation to the increased water temperature. If this is any indication of its temperature requirement, as waters in the Great Lakes region warm, this invader will thrive in the new climate, spreading rapidly to become an even bigger problem.

Effects of Global Climate Change

It is very likely that this bivalve will be a permanent part of the Great Lakes environment. It is limited to waters with a temperature between 12-27°C. As global warming increases the temperature of the Great Lakes, it will spread faster north into warmer waters. As the water level in the Great Lakes recedes, it will be able to colonize new areas that at one time were too deep for its survival.

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Effects of Global Climate Change

This invertebrate is sensitive to water temperature increases above 25°C, as is noted in the Western Basin of Lake Erie. As water temperatures increase, they will move into colder, deeper parts of the Great Lakes, where temperature conditions are more hospitable.

105

Effects of Global Climate Change

The effects of global climate change on this invading fish are unknown at this time. It is an aggressive competitor that extends well north of the Arctic Circle and tends to dominate any ecosystem it enters. It is predicted to spread throughout North America. This invader is so new that temperature effects are as yet unknown.

Effects of Global Climate Change

As waters warm, walleye and yellow perch may seek cooler waters in the deeper areas of the Great Lakes, leaving the shallower areas to this competing fish. Without competition of the other species, this invader will be able to reproduce into an even larger population, competing with still more species.

Effects of Global Climate Change

These herring-like fish need deep water with moderate temperature to overwinter. A rise in water temperature would probably result in fewer die-offs and would enable the fish to be more abundant in Lake Superior, where they currently are scarce. This would certainly alter local fisheries, but the specific impacts are not yet clear.

Effects of Global Climate Change

As water levels decrease, this invader will find new wetlands in which to spread, choking out more and more vegetation as it follows the receding waterline.

Ohio Sea Grant Education Program

Answers to Cards

Invader 1: Zebra mussel (*Dreissena polymorpha*)
Introduction: Originally, it came from the Caspian Sea region of Poland, Bulgaria, and Russia. Canals built during the early 1800s allowed it to spread throughout Europe. By 1830 it had invaded Britain. First introduction into the Great Lakes was about 1985, when one or more transoceanic ships discharged ballast water into Lake St. Clair. Freshwater ballast from a European port likely contained larvae and possible yearlings. Being a temperate, freshwater species, it found the plankton–rich Lake St. Clair and Lake Erie to its liking.
Ecosystem Impact: It filters the plankton from the water, binding what it doesn't use into pellets that cannot be used by other plankton–feeding organisms. It accumulates on objects such as boat hulls and underwater pipes, clogging valves of both industrial and municipal water intake sources.
Effect of Global Climate Change: It is very likely that this bivalve will be a permanent part of the Great Lakes environment. It is limited to waters with a temperature between 12° C to 27° C. As global warming increases the temperature of the Great Lakes, it will spread farther north into warmer waters. As the water level in the Great Lakes recedes, it will be able to colonize new areas that at one time were too deep for its survival.

Invader 2: Sea Lamprey (*Petromyzon marinus*)
Introduction: Originally it came from the Atlantic Ocean, the St. Lawrence and Hudson Rivers,, and their tributaries for spawning, and possibly Lake Ontario. It swam from Lake Ontario into Lake Erie through the Erie and Welland Canals, gaining entry into the upper Great Lakes by attaching to hulls of boats.
Ecosystem Impact: It destroys valuable fish, especially lake trout, by attaching with its sucker–like mouth to suck out blood and body tissues. It upsets the ecological balance by removing top predators, allowing for explosion of populations of smaller fish such as alewives. It had great economic impact on the commercial fishing industry of the Great Lakes during the 1950s.
Effect of Global Climate Change: Warmer stream temperatures create a more favorable environment for this parasitic organism, enabling it to spawn successfully at more locations throughout the Great Lakes basin. This could result in an increase in population that may further upset the ecological balance of the Great Lakes.

Invader 3: Spiny Water Flea (*Bythotrephes cedarstromi*)
Introduction: A native of northern Europe, it made its way into Lake Huron in 1984 and was present in all Great Lakes by 1987. It is believed to have been brought over in fresh water or mud in ballast water of European freighters from Eastern Baltic Ports, as studies show that the Great Lakes species closely resembles the species in the ports of Finland and St. Petersburg (the former Leningrad).
Ecosystem Impact: This is a large plankton form that eats the smaller plankton, thereby competing with small fish for their food source and affecting their survival and growth rates. Its spiny tail prevents young fish from swallowing it, thus removing it from the food chain. It is an invader species so new that it may take years to determine its total impact.
Effect of Global Climate Change: This invertebrate is sensitive to water temperature increases above 25° C, as is noted in the Western Basin of Lake Erie. As water temperatures increase, they will move into colder, deeper parts of the Great Lakes, where temperature conditions are more hospitable.

Invader 4: River Ruffe (*Gymncephalus cernuus*)

Introduction: Arriving from the freshwater and brackish water in northern Europe, this invader was discovered in Lake Superior in 1986. It is assumed that it "hitchhiked" in ballast waters from Europe and Asia. In 5 years, its population reached 1.8 million adults, making it the most abundant fish in the Duluth harbor. This bottom feeder can reproduce in its first year, and the females may lay between 13,000 to 200,000 eggs per season.

Ecosystem Impact: Only about 8 inches long, this perch–like fish has little value as a sport or food fish. It is less temperature-dependent than perch and tolerates more polluted areas. It also can find hidden prey in soft sediments more efficiently than its competitors. This fish is not preferred by predators because of its spiny fins. It displaces sport and food fish, especially perch and walleye, yet is not readily consumed in the food web. This invader made up 90 percent of the fish population in the Scottish lake, Loch Lomond, only 9 years after it was introduced.

Effects of Global Climate Change: The effects of global climate change on this invading fish are unknown at this time. It is an aggressive competitor that extends well north of the Arctic Circle and tends to dominate any ecosystem it enters. It is predicted to spread throughout North America. This invader is so new that temperature effects are as yet unknown.

Invader 5: Alewife (*Alosa pseudoharengus*)

Introduction: Coming from the salty Atlantic Coast, this invader migrated through water routes, including canals in New York state and the St. Lawrence River. It swam into the upper Great Lakes through the Welland and/or Erie barge canal before 1931.

Ecosystem Impact: Large numbers die off in spring and summer because of electrolyte imbalance from living in fresh water. These die–offs clog municipal and industrial intake pipes and foul beaches. In 1967 bulldozers had to remove 50,000 tons of the rotting fish. The sea lamprey enabled this invader to thrive in Lake Erie by killing lake trout and other fish at the top of the aquatic food chain. After the sea lamprey arrived, this invader proliferated. Between 1960 and 1966, for example, they went from representing 8 percent to 80 percent of Lake Michigan's fish by weight. Presently this invader is forage for larger game fish.

Effect of Global Climate Change: These herring–like fish need deep water with moderate temperature to overwinter. A rise in water temperature would probably result in fewer die–offs and would enable the fish to be more abundant in Lake Superior, where they currently are scarce. This would certainly alter local fisheries, but the specific impacts are not yet clear.

Invader 6: White Perch (*Monrone americana*)

Introduction: From saltwater areas of the Atlantic coast, this invader moved up the Hudson River and via various canal systems into Lake Ontario and Lake Erie.

Ecosystem Impact: Suspected to be partially responsible for the decline of Lake Erie's yellow perch because of competition.

Effect of Global Climate Change: As waters warm, walleye and yellow perch may seek cooler waters in the deeper areas of the Great Lakes, leaving the shallower areas to this competing fish. Without the competition of the other species, this invader will be able to reproduce into an even larger population, competing with still more species.

Invader 7: Purple Loosestrife (*Lythrum salicaria*)

Introduction: This species was intentionally imported from Northern Europe over 100 years ago, because its hardiness and beautiful flowers were popular with landscapers, florists, and gardeners.

Ecosystem Impact: It is called "the beautiful killer," because its dense roots choke waterways as it competes with other vegetation. It spreads quickly, crowding out valuable plants that provide food for migrating waterfowl, and destroys habitat for almost all other forms of wetland life.

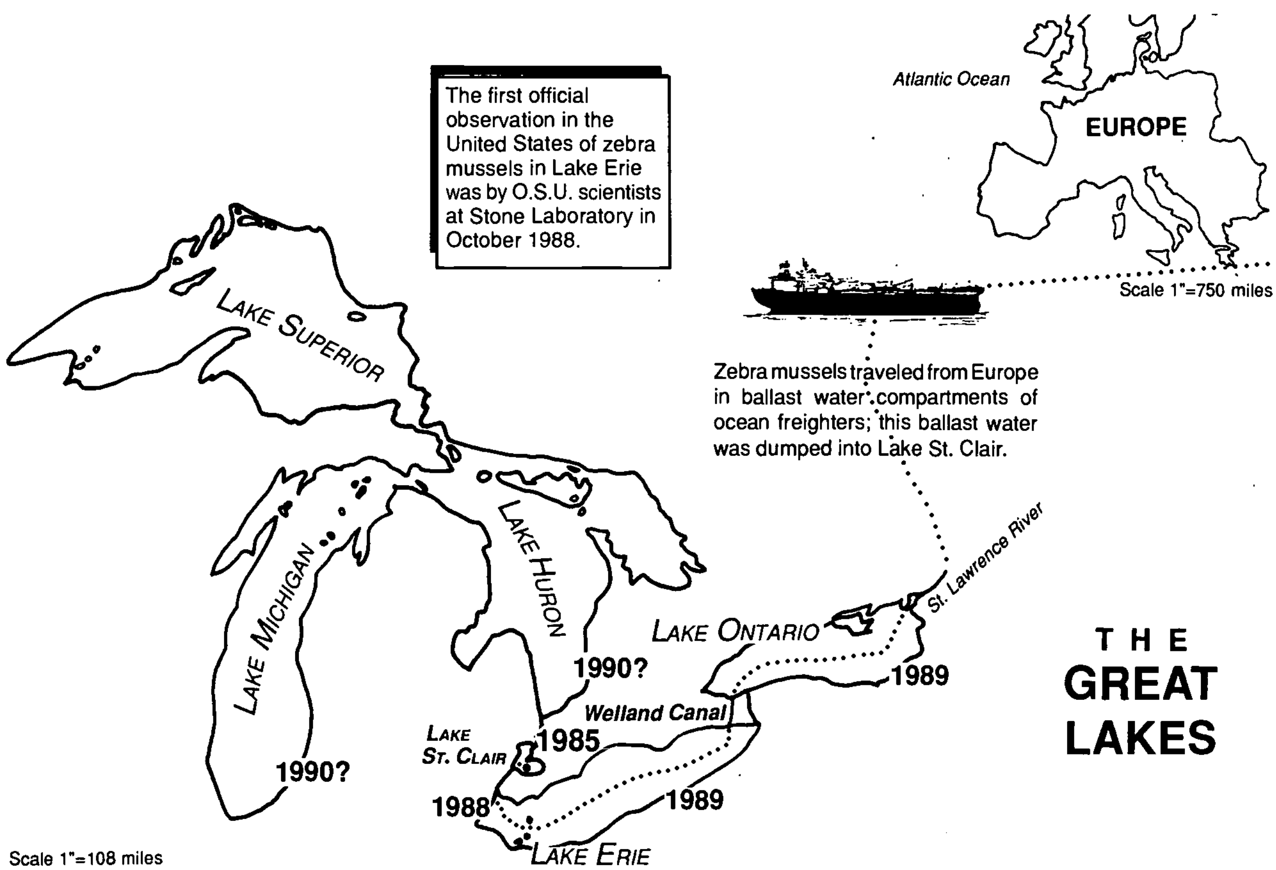
Effect of Global Climate Change: As water levels decrease, this invader will find new wetlands in which to spread, choking out more and more vegetation as it follows the receding waterline.

Invader 8: Eurasian Water Milfoil (*Myriophyllum spicatum)*

Introduction: It came from Europe, Asia, and North Africa and was introduced into North America as an aquarium plant. It has since spread to 37 states and 3 Canadian provinces.

Ecosystem Impact: Forms thick mats that choke out native aquatic vegetation. It disrupts all forms of water recreation —boating, swimming, and fishing.

Effect of Global Climate Change: This plant thrives as waters warm each summer, increasing in volume in relation to the increased water temperature. If this is any indication of its temperature requirements, as waters in the Great Lakes region warm, this invader will thrive in the new climate, spreading rapidly to become an even bigger problem.



Biodiversity: Great Lakes Fish

Global warming is predicted to cause many changes in the Great Lakes region and all over the world. The water temperature of the Great Lakes is expected to increase between 3-5 °C, showing the most effect in shallow lakes. Lake Erie is the shallowest of the Great Lakes, with an average depth of only 19 meters, and the deepest area being 64 meters. Compare this to Lake Superior, with an average depth of 147 meters, and the deepest area being over 405 meters.

Increased evaporation will, it is projected, decrease stream flow and decrease lake levels from 1 to 3 meters, thus affecting fish spawning habitats. Other areas may temporarily experience raised water levels, which would also affect spawning habitats. Water level changes, such as those that might occur in the Western Lake Erie Basin, are directly tied to the success of the fish in their spawning habitat. If the spawning habitat is destroyed, then the successful reproduction of the species is in danger. Even though it appears that fish prefer shorelines for spawning, the new shoreline created by lowered lake levels may not be suitable for new spawning grounds, because the bottom has not had time to become covered with silt deposits. Lowered fish populations would endanger the viability of the fish species, as well as the commercial and recreational fishing industries. The same can happen in any shallow area of the Great Lakes where fish are spawning. Lake Erie is used because of the variety of examples available.

If the spawning habitat of a particular fish species is destroyed in the Western Basin of Lake Erie because of the decreased water level associated with global warming, there are other factors that influence whether that species of fish will be able to migrate to other, more favorable locations. Different fish species prefer different temperatures. These preferred habitats fall into three *thermal niches* (temperatures, ± 2°C, that the fish can tolerate and still be successful in their feeding and reproduction). The cold water fish prefer water temperatures around 15°C; cool water fish prefer water temperatures around 24°C; and warm water fish prefer water temperatures around 28°C. Global warming would change the thermal environment of the fish of the Great Lakes, and in some cases the fish might not be able to find water temperatures that were suitable.

The waters comprising the Great Lakes and tributaries of today contain representatives of the most important families of fish in North American fresh waters. Since the entire natural drainage area was once covered by ice, fishes now present include populations that were "pushed" southward as the glaciers advanced and those that reinvaded the basin from other regions following the recession of glaciers. Some species are thus at the southernmost edge of their range or the northernmost edge of their range.

With the increase of global temperatures, the water temperatures of the Great Lakes would also rise. Fish may have to migrate as much as 200 kilometers north of their present geographic region to maintain their current thermal niches. For instance, the warmer stream temperature in tributaries could be beneficial to species such as the white perch, while some cool water and warm water fish may extend their range into Lake Superior streams that are currently too cold. Research among numerous ecosystems indicates that climate-related biodiversity changes have occurred in the past and are in progress now.

Researchers from Stanford University's Hopkins Marine Station have uncovered a shift in the distribution of some invertebrate species in California's Monterey Bay. A survey of all of the species in a particular area was conducted in 1931-33. After recounting the species in that same location about 60 years later, the researchers found that populations of eight of the nine southern species had increased, while populations of five of the eight northern species had decreased. These changes suggest that in Monterey Bay species adapted to warmer waters are replacing those adapted to cooler seas. Temperature data show that the annual mean shoreline ocean temperature at the study site increased by 1.35 degrees in the past 60 years and that mean summer maximum temperature increased by 4 degrees. It is rare to have data on the abundance of an entire animal community spanning 60 years, and the evidence in this case appears to support the idea that the effects of global warming may already be apparent in the Northern Hemisphere.

Water plants have also been observed to migrate. For example, twenty species of flowering plants are no longer present in Put-in-Bay Harbor. Eleven of those species occur principally in cool water habitats, mostly to the north of Lake Erie. The northern species are less tolerant of warmer water conditions and more tolerant of well oxygenated ponds and lakes than of eutrophic conditions.

Similar research was also done in on Atlantic Salmon, a dominant fish species in Lake Ontario. Atlantic Salmon were planted in Duffin Creek, a tributary of Lake Ontario that had been a good salmon stream in the mid-1900's. Scientists discovered two causes of mortality: inadequate shelter as a result of deforestation, and high water temperatures in lower parts of the stream. Before the forests were cut, stream temperatures for July, August, and September averaged 11°C, with a fluctuation of 8.9° to 13.7°C. Following forest removal, the water temperature averaged 15°C, with a fluctuation of 9.2° to 25.5°C. Young salmon spend two years in streams. The young fish have maximum food conversion at 11.7°C and thrive in streams with water temperatures of 12.8°C. The increase in water temperature to 15° and higher led to the decline and eventual extinction of Atlantic Salmon in the Great Lakes.

The fish in the Great Lakes are useful as biological indicators. Their survival in the region as global climate change becomes more apparent will be interpreted as a measure of the impact of the climate changes overall. Environmental changes that may impact the fish populations include loss of spawning habitat as water levels lower, thermal range shifts as water temperatures warm and seasons are altered, increase in toxic contamination if pollutants become more concentrated, and increase in fishing pressure because of longer recreational seasons. This activity will consider two factors, thermal range shifts and lower water levels, and their potential effect on several species of Lake Erie fish. It is plausible that with global warming, fish species that are not located in the Great Lakes will be able to move into that area as the temperature approximates their thermal niche.

Activity: How will global warming affect spawning success of Great Lakes fish?

This activity consists of two parts. The first pertains to the effect of lower lake levels on spawning and nursery grounds, and the second pertains to the effects of increased temperature and the ability of fish to migrate to favorable temperatures. These are then combined to help the students anticipate the future of specific fish populations in the Great Lakes if global warming were to occur.

OBJECTIVE

Students should be able to summarize effects of lake level change on the spawning and nursery grounds of given fish in the Great Lakes, using Lake Erie examples.

PREPARATION

- Copy the Western Basin of Lake Erie maps for each lab group.
- Copy fish sheets so that each group gets a description of one fish with the accompanying picture and map of spawning and nursery grounds.
- Copy an outline map of North America for each group.

PROCEDURE

Part 1: Lower lake levels and spawning grounds

1. Students should be divided into groups so that each group studies a different fish.

Each group of students should:

2. Obtain a fish sheet and a Western Basin Lake Erie map.
3. Transfer information from the given fish map concerning spawning and nursery grounds (on fish sheet) to the Western Lake Erie map with water depths. Remember to enlarge the information (the circles that indicate spawning areas) while transferring them from a small to a larger-scale map.
4. Set up a chart and record the amount of spawning and nursery areas before the predicted global warming.
5. Draw a line depicting a 3-meter lake level drop on the Western Basin Lake Erie map in order to determine which spawning and nursery areas would remain usable.
6. Set up another chart and record the amount of the original spawning and nursery area that remains with the new lake water level.

Earth System Understanding

This activity focuses on ESU #3 (science methods and technology) and #4 (interactions). Refer to the introduction of this book for a more complete description.

Scenario Reference

#9, How could fish populations in the Great Lakes be affected?

Materials

- fish sheets (one fish for each group of three to four students)
- colored markers, pens or pencils
- map of the Western Basin of Lake Erie
- transparency of the fish range summary chart
- overhead projector
- outline map of North America

7. Use this information to answer questions a-f.

   a. Where are the majority of your fish's spawning and nursery grounds?

   b. Looking at the location of your fish's spawning and nursery grounds, predict the effect (little or none, moderate, high) that lowered lake levels would have on your fish.

   c. Based on your data, what kind of effect could lower lake levels have on the given fish species?

   d. How do the lower lake levels affect your fish's habitat?

   e. What kind of effect would the above situation have on commercial fishing? On recreational fishing?

   f. What are some other factors besides water level that could affect the size of the given fish species population?

8. Transfer the information from each group to an overhead transparency and answer questions g-i.

   g. What kind of an effect on the fish would a gradual global warming versus a rapid global warming have?

   h. In this exercise, we used the predicted maximum water level drop of 10 feet. However, a 3-foot water drop might also occur. How would this new level affect your fish species? Explain.

   i. After reviewing all of the fish, which fish would be better adapted for this drop in water level?

If global warming does occur and causes the lake level to drop by 3 meters, the various fish populations will be impacted, but the degree of this impact can only be speculated. This exercise illustrated the maximum effect of a lake level drop, but we also have to look at other factors, such as temperature and food supply, which may affect fish populations. Even if the fish are shown to be somewhat successful in maintaining a spawning and nursery habitat, the water may become too warm for them to live in or their food supply may be affected. Therefore, even though we can see the effects of lowered lake levels, this is just one factor among many that will affect the fish populations.
The second part of this activity considers the same fish but concentrates on the thermal niche of the fish species.

Answers

a. They are most often in the shallow waters near the shoreline or in streams that flow into or out of the lake.

b. Students should predict that many of these areas will dry up. They may assume that the fish could spawn in the new shallow waters, since a decreased water level does not eliminate shallow water. This is usually not the case, however, because the new shallow waters have not had time to accumulate the sediment necessary for the fish, and the coast will most likely be a steeper incline until natural erosion has time to take its course.

c. In most cases, the amount of spawning and nursery areas will decrease.

d. It decreases the amount of habitat available and eliminates the existing one. The fish that spawn in shallow water and grow the first year in protected shallow water will be affected the most until the deposition of the silt gradually fills in the shoreline.

e. There will be less water available for the fish to live in. There will be fewer spawning grounds, resulting in less fish available for consumption. For these two reasons, the commercial fishing will be sharply restricted to the point that it will no longer be economically feasible for many to pursue as a living. The recreational fishing will continue but at a very restricted and reduced rate such as a larger fish size and a smaller number limit.

f. Warmer water, increased pollutants, food supply change, and eutrophication.

g. A rapid global warming would have the greatest impact, possibly a population crash. The environment needs time to compensate and recover. A gradual warming would allow the bottom to slough off, creating a new shoreline, thus providing an acceptable location for the fish to spawn.

h. Generally, the 3-foot drop would not have as much of an impact as the 10-foot drop. Less habitat would be destroyed.

i. The fish which spawn in deeper water or spawn in more places.

Part 2 : Increased temperature and thermal niches

1. Look at the habitat range for your fish on the map of North America on the fish sheet and answer the following questions:

   a. Is your fish at the southern limit of its range, northern limit, or neither? Compile the answers from all the groups on the first half of an overhead of the Fish Range Summary Chart.

   b. What would happen if the temperature increased 3-5°C. What conclusions can be made about the future populations of the given fish in Lake Erie (second half of *Fish Range* chart).

   c. Based on the Fish Range chart, generalize the effects of warmer water temperatures on the types of fish found in the Great Lakes.

   d. Brainstorm and analyze the environmental factors that could influence fish in the Great Lakes under warmer climate conditions.

2. Use the information located on the fish card and a reference book to help determine the preferred general water conditions, bottom conditions, and food sources of the fish. With this information, and the present habitat of your fish, predict where the fish would go if the global temperature rose 1.5 to 4.5 °C. Use a map of the North America to shade in the new area of habitat, assuming temperature as the only variable.

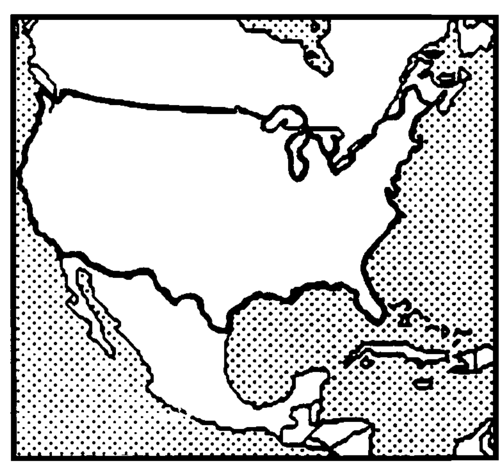
3. Combine all of the charts to see which of the fish in question will still be located in the Great Lakes.

Answers

b. Many species will move farther north or deeper into the Great Lakes, while other species move out to the upper lakes.

c. Some fish species that are presently not found in the Great Lakes may move into the lakes as the temperature changes to accommodate them. Many of the fish presently living in the Great Lakes will leave as the environment changes.

d. The level of water contamination, food supply, and abundance of predators are all factors that will affect fish populations as the temperature increases.



Answers

1. Answers will vary based on school location. In general, there will be fewer habitats available for cold water fish like trout, cisco, and whitefish. Fish of the herring and minnow families, including alewife, carp, and shiners, may have greater success (more habitat available), and some fish like yellow perch and walleye will probably remain unchanged.
2. Impact webs are like concept maps or the "More or Less" activity in this volume. Beginning with a certain change, students think outward to all the connections that would be changed as well. The relationships are very complex, especially if impacts on human activity are also considered.

Teacher's Note

Students should not assume that there will be less fish in the Great Lakes because of global warming. In order to find out the total fish picture for the Great Lakes, all species of fish located in or close to the Great Lakes would need to be examined.

Review Questions

1. Considering the kinds of fish that may be impacted by a changing thermal habitat, should humans expect a changed menu of seafood in the future? Which popular food fish may leave or come into your region of the lakes? If the food fish remain, will <u>they</u> still be able to find their preferred food?

2. Develop an impact web showing how the introduction or loss of a fish species could impact the Great Lakes and the people who depend on the lakes. Is a change in the composition of an ecosystem a simple matter of checks and balances, or is each impact of environmental change worthy of serious consideration? Explain.

Extensions

1. Suppose a fishery biologist, in reviewing the "creel census" for the past three years, discovers that the catch of northern finwavers has declined significantly. Make a list of possible reasons for this observation, and tell how you would determine which reason was the most likely one. What other kinds of data do you need? Who would you consult for information?

2. Develop a Hypercard stack or other computer program demonstrating the possible scenarios for several kinds of fish as temperatures of Great Lakes water become warmer.

3. There are many other animals and plants that depend on the Great Lakes for survival. Compile a list of the animals and plants and show how a warmer lake temperature might affect each species.

4. Create a poem or lyrics to a song to show the effects that global warming would have on the fish species of the Great Lakes.

FISH RANGE SUMMARY

Classify the following fish according to their present range. Do those in the Great Lakes appear to be at the southern limit of their range, the northern limit, or neither? Are there likely to be more, fewer, or generally an unchanged number of the fish in the Great Lakes with global warming?

	Current Range ( )			Prediction with global warming		
Fish	S limit	N limit	Neither	more	fewer	unchanged
Yellow Perch						
Walleye						
Freshwater Drum						
Lake Trout						
Gizzard Shad						
Channel Catfish						
White Bass						
Carp						
Northern Pike						
Cisco						
Whitefish						
Smallmouth Bass						
Emerald Shiner						
Rainbow Smelt						

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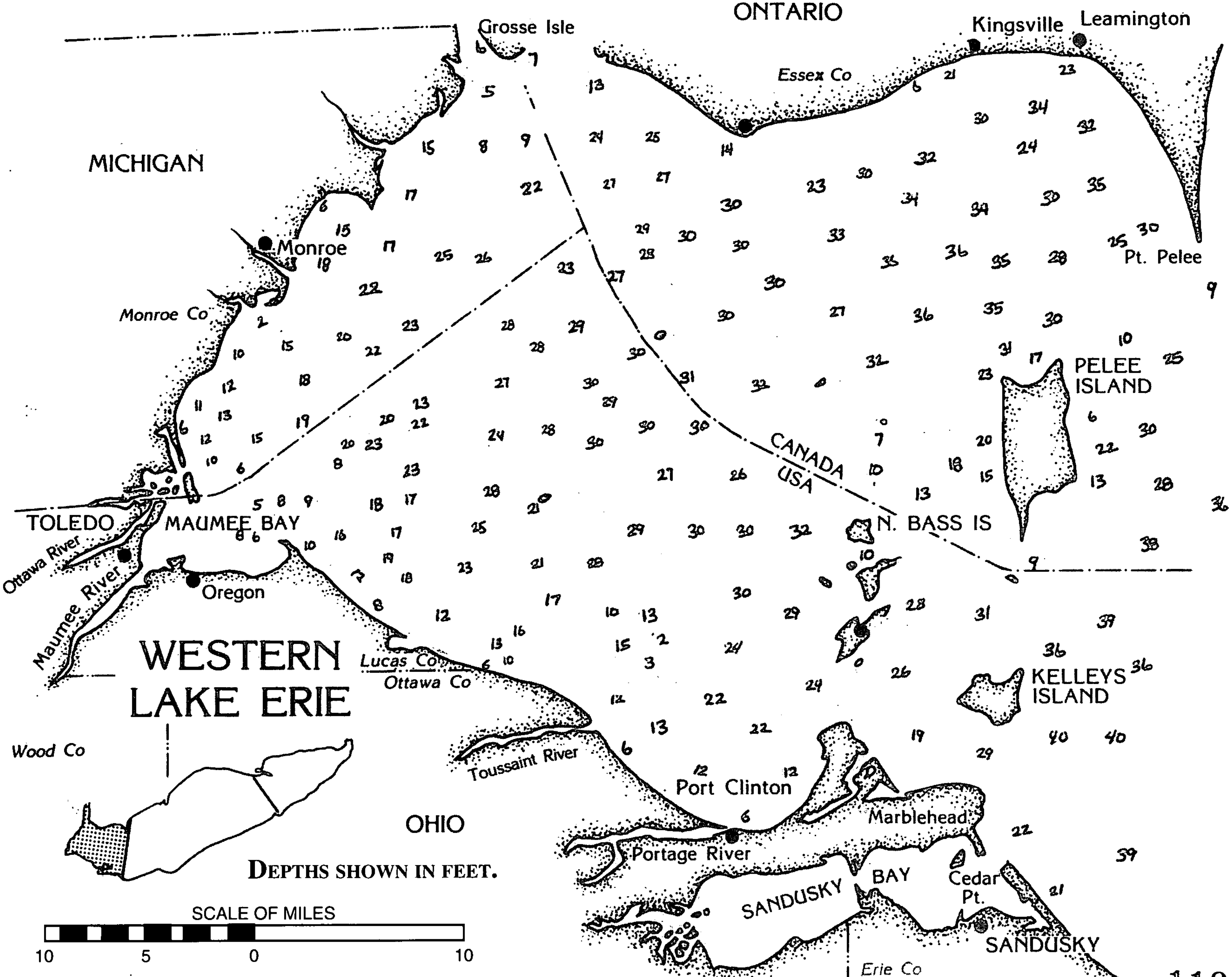
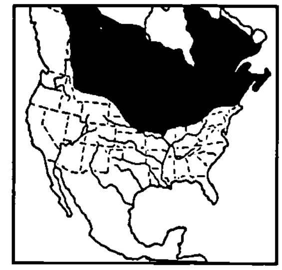
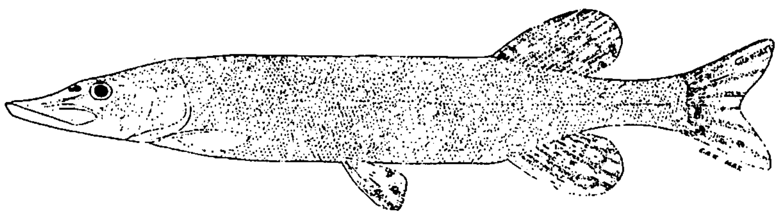
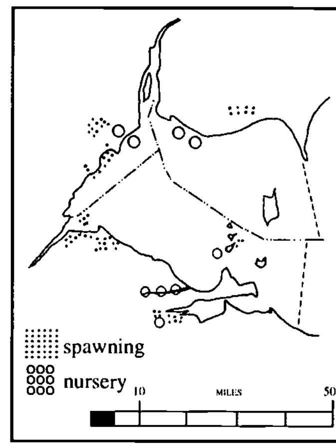

WESTERN
LAKE ERIE
DEPTHS SHOWN IN FEET.
SCALE OF MILES
10
5
0
10
MICHIGAN
ONTARIO
OHIO
Grosse Isle
Kingsville
Leamington
Essex Co
Pt. Pelee
Monroe
Monroe Co
TOLEDO
MAUMEE BAY
Ottawa River
Maumee River
Oregon
Lucas Co
Ottawa Co
Wood Co
Toussaint River
Port Clinton
Portage River
Marblehead
SANDUSKY
BAY
Cedar
Pt.
SANDUSKY
Erie Co
CANADA
USA
N. BASS IS
PELEE
ISLAND
KELLEYS
ISLAND

Northern Pike

- adult size: 19-37 inches (48.3-93.9 cm) long, 2-12 pounds (.9-5.4 kg)
- dwells in open waters of lakes, ponds or streams
- lays eggs over vegetation in shallow water (swampy, marshy areas)
- consumes other fish as well as mice, muskrat, ducklings, or frogs



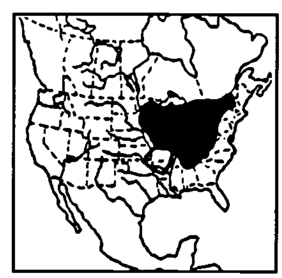


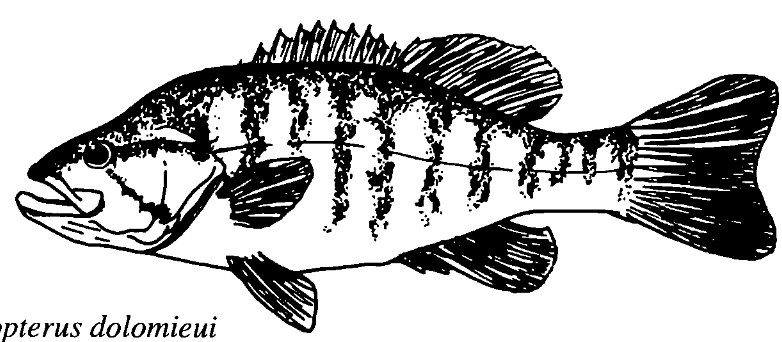


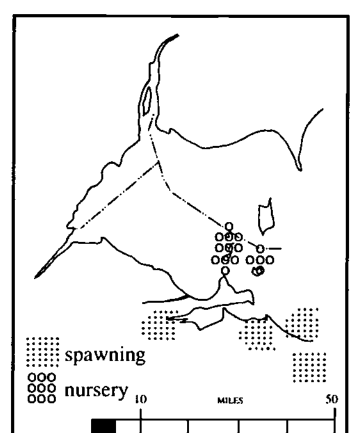
Esox lucius
(Northern Pike)

Smallmouth Bass

- adult size: 10 - 18 inches (25.4-45.7 cm) long, 11 oz - 3 lbs 2 oz (312 g - 1.4 kg)
- spring and early summer spawners in streams with visible currents
- males often guard the larvae and young
- as they develop they first eat microorganisms; later they eat aquatic invertebrates and then other fish
- inhabits shallow areas (less than 1.5 meters) which are subject to damage from storms, low water levels and increased siltation



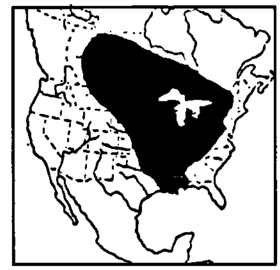


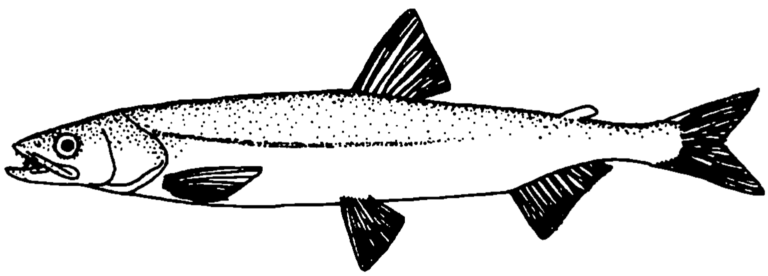


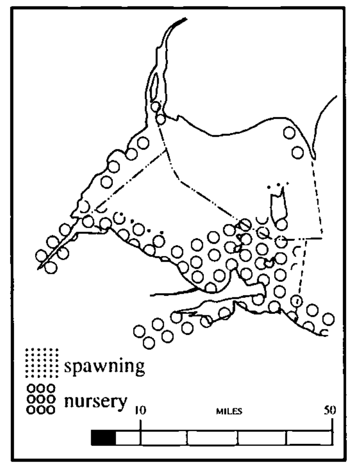
Micropterus dolomieui
(Smallmouth Bass)

EMERALD SHINER

- adult size: 2.5 - 3.3 inches (6.4 - 8.4 cm)
- habitat restricted to the Great Lakes
- important in food chains of all predacious fish
- variety of spawning habits



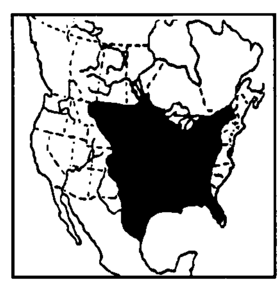


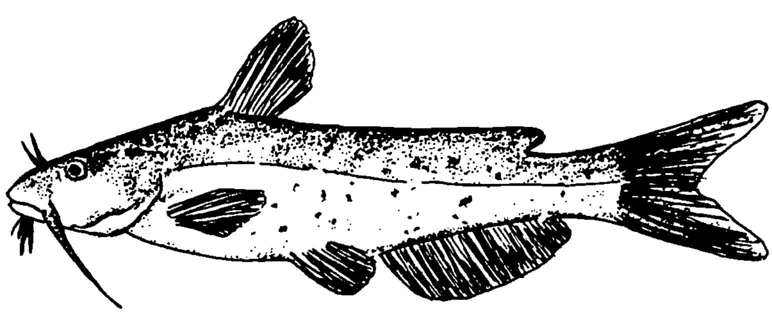


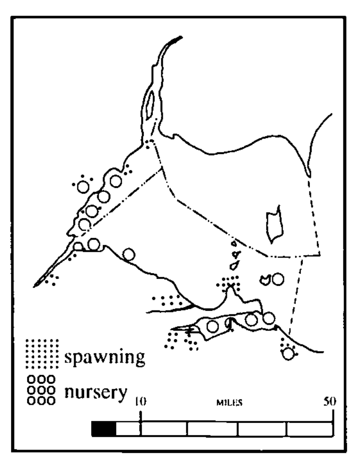
Notropis atherinoides atherinoides
(Emerald Shiner)

CHANNEL CATFISH

- adult size: 11 - 30 inches (27.9 - 76.2 cm) long, 12 oz - 15 lbs (340 g - 6.8 kg)
- occur in deep and large waters of low gradients with clean bottoms of sand, gravel or boulders; found where silt deposition is slow; seldom found in dense beds of aquatic vegetation
- feed on fish and invertebrates such as aquatic insects and larvae

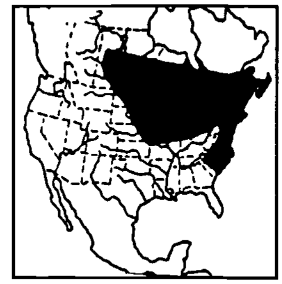




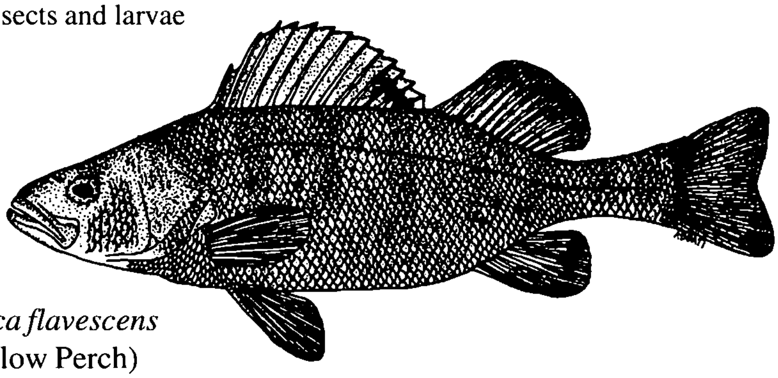


Ictalurus punctatus
(Channel Catfish)

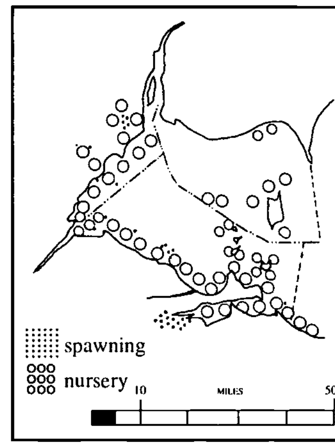
YELLOW PERCH



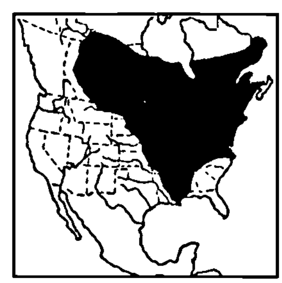
- adult size: 4.5 - 12 inches (11 - 30.5 cm) long, .8 oz - 1 lb 2 oz (23 g - .5 kg)
- occurs in shallow waters with clear, low gradients and a lot of rooted aquatic vegetation; bottoms of muck, organic debris, sand or gravel
- lays a zigzag ribbon (rope) of eggs on vegetation in moderately shallow waters
- history of decreased population because of increased turbidity and siltation and reduced amounts of rooted aquatic vegetation in spring
- eats microscopic animals when young, then aquatic invertebrates, insects and larvae



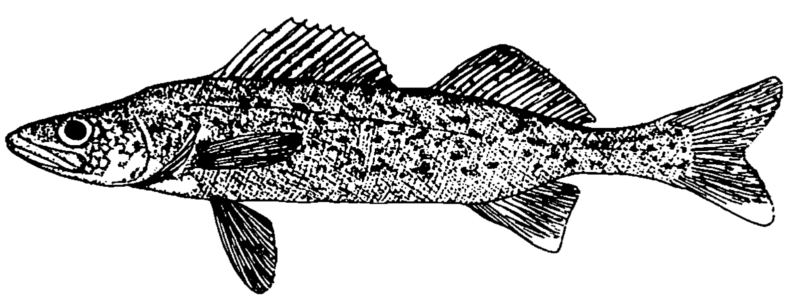
Perca flavescens
(Yellow Perch)

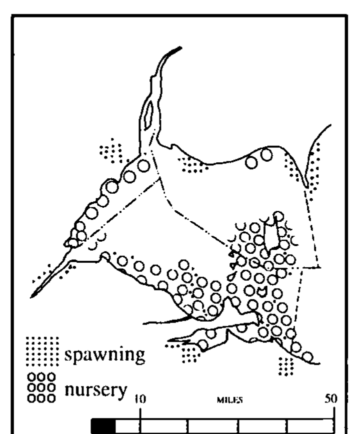


WALLEYE



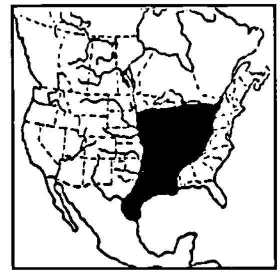
- adult size: 11 - 30 inches (27.9cm - 76 cm) long, 8 oz - 1 lb (227 g - .5 kg)
- found in large, deep, clear streams; also in shallow water over gravel bedrock or firm bottoms with decreased turbidity
- scatters eggs on bottom in shoal areas in spring
- eats microscopic animals when young, then aquatic invertebrates, insects and larvae



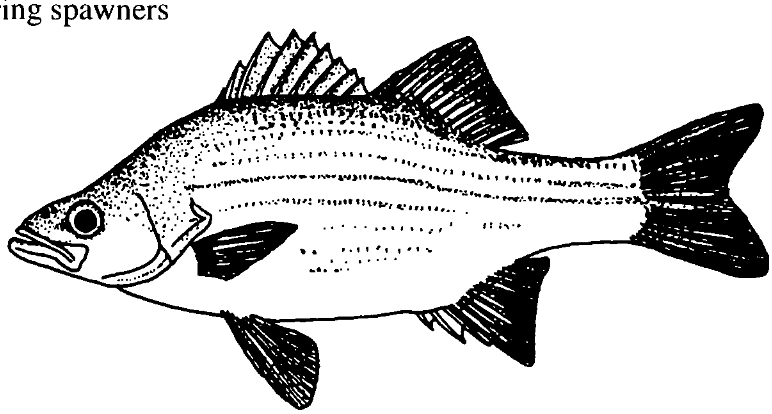


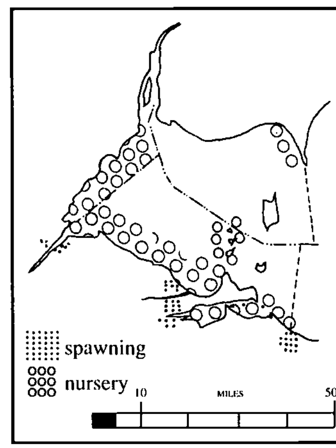
Stizostedion vitreum vitreum
(Walleye)

White Bass



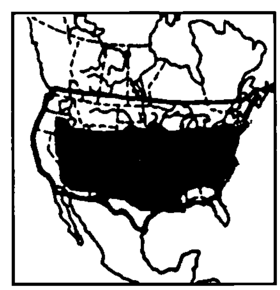
- adult size: 7.5 - 16 inches (19 - 40.6 kg) long, 3 oz - 2 lbs 3 oz (85 g - 1 kg)
- inhabits clear water with firm bottom not of silt
- found wherever there are a lot of small fish and insects to eat
- spring spawners



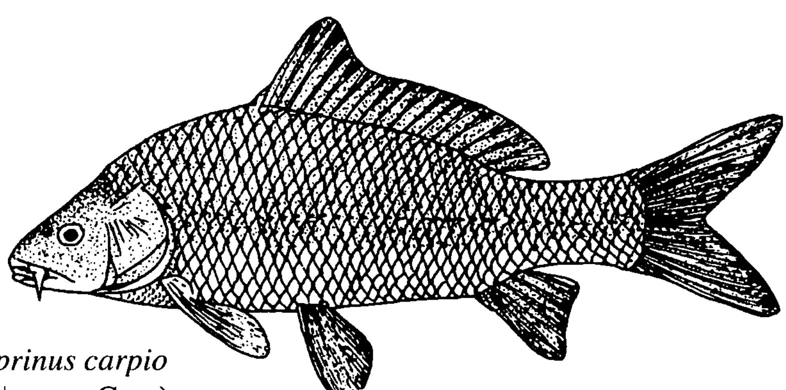


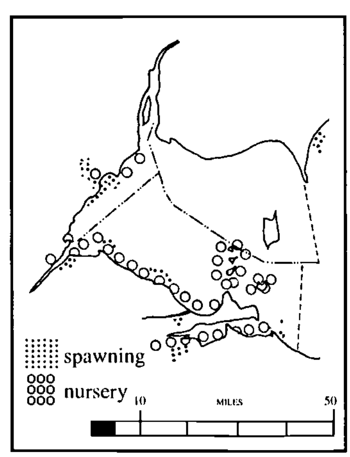
Morone chrysops
(White Bass)

Carp



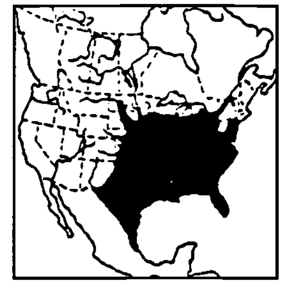
- adult size: 12 -30 inches (30.5 - 76.2 cm) long, 14 oz - 20 lbs (397 g - 9.1 kg)
- found in low gradient warm streams and lakes with much organic matter (such as sewage and fertilizers)
- eat rooted aquatic vegetation
- tolerate all types of bottoms, clear or turbid water but rarely found in cold, clear, high-gradient streams
- spread eggs on bottom vegetation



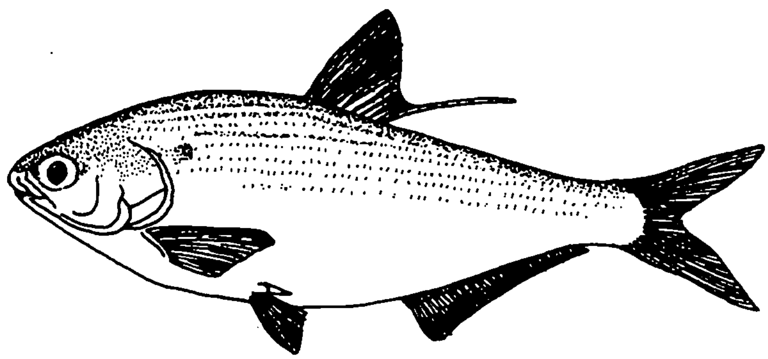


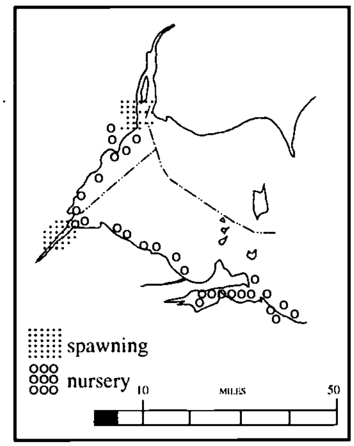
Cyprinus carpio
(Common Carp)

Gizzard Shad



- adult size: 12 - 16 inches (30.5 - 40.6 cm) long, 10 oz - 1 lb 8 oz (283 g - .7 kg)
- found in low gradient, clear or turbid water wherever the phytoplankton production is high
- winter kills easily
- forage organism for other fish
- filter feeder

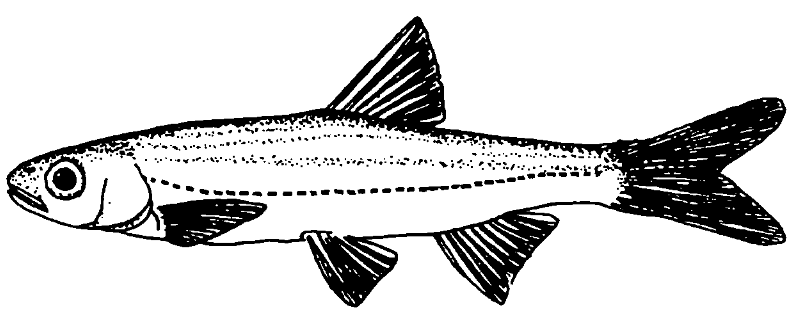


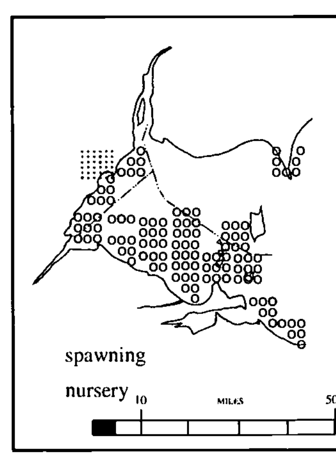


Dorosoma cepedianum
(Gizzard Shad)

Rainbow Smelt

- adult size: 7 - 10 inches (18 - 25.4 cm) long, 2 oz - 4 oz (57 - 113 g)
- inhabits deep water; however, adults are found in shallow waters in spring for spawning
- eats small fish and invertebrates (insects)

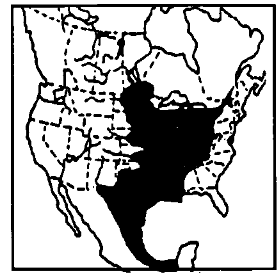


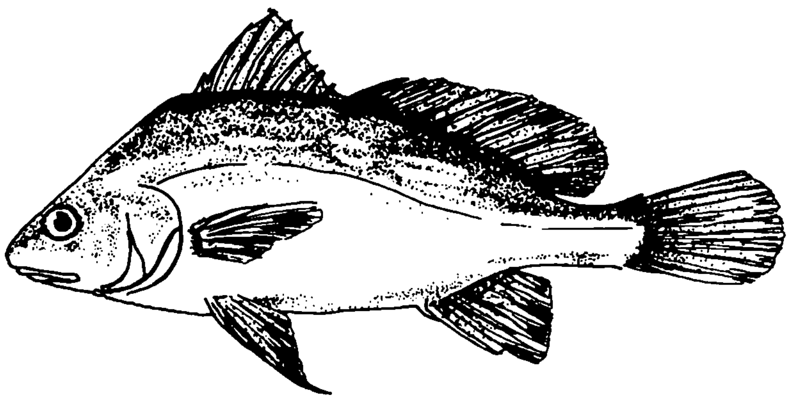


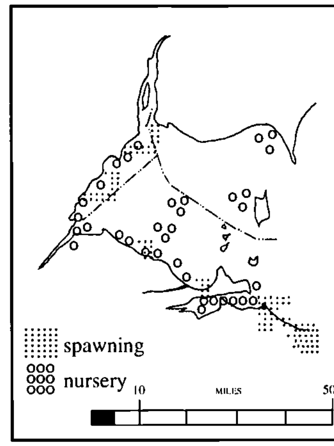
Osmerius mordax
(Rainbow Smelt)

Freshwater Drum

- adult size: 12 - 30 inches (30 - 76.2 cm) long, 1 - 17 lbs (.5 - 7.7 kg)
- inhabits shallow turbid waters
- spring spawners
- feeds on microscopic organisms, then aquatic insects and small crustaceans; when grown eats snails and clams



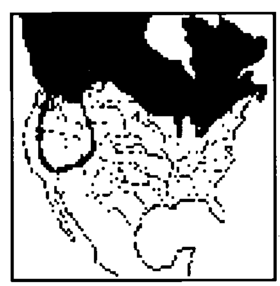


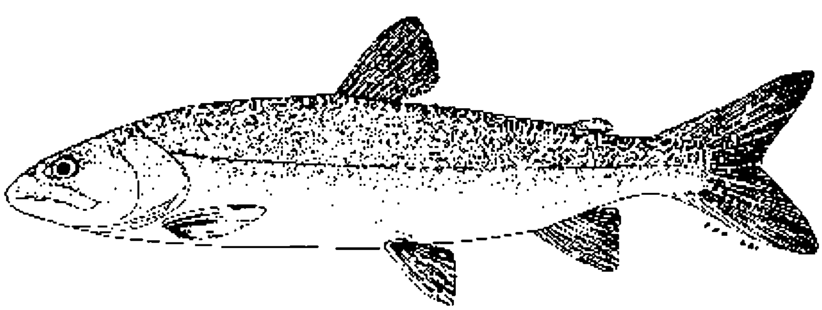


Aplodinotus grunniens
(Freshwater Drum)

Lake Trout

- adult size: 15 - 36 inches (38.1 - 91.4 cm) long, 1 - 20 lbs (.5 - 9.1 kg)
- populations in the Great Lakes have greatly declined since the 1900s. In 1975 the fish was very rare and was thought to have possibly been extirpated; presently there are few located in Lake Erie
- lives in deeper waters of the eastern half of Lake Erie

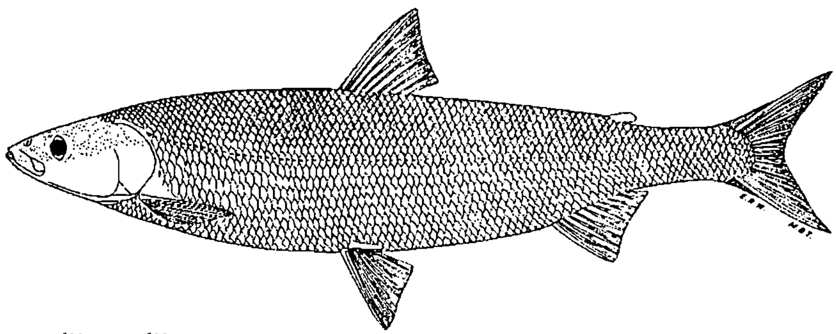




Salvelinus namaycush (Walbauwm)
(Lake Trout)

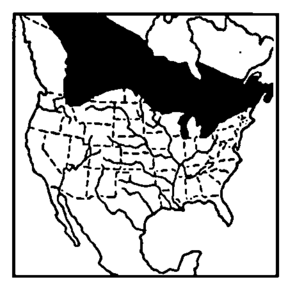
Great Lakes Cisco

- adult size: 11 - 15 inches (27.9 - 38.1 cm) long, 9 oz - 1 lb 9 oz (255 g - .7 kg)
- inhabits moderately deep water
- distinctly bluish back
- populations in Lake Erie have been continuously declining since 1885 Presently there are very few remaining. Between 1938 and 1947, the annual catch varied from 8,594 lbs (3,898 kg) to 76,919 lbs (34,890 kg). In 1968 only 5 lbs (2.3 kg) were caught.

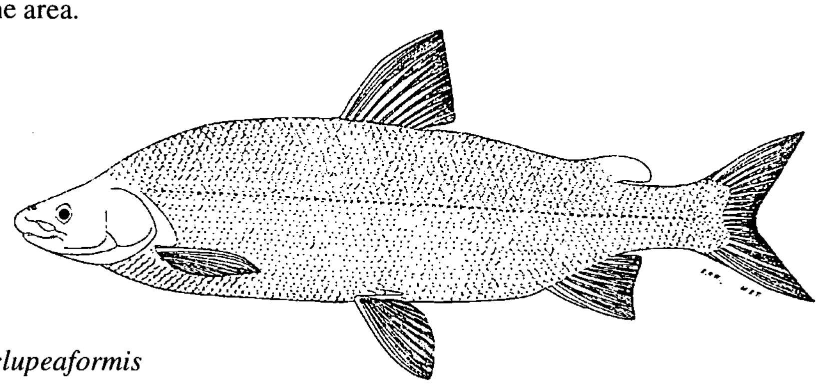


Coregonus artedii artedii
(Great Lakes Cisco)

Lake Whitefish



- adult size: 17 - 22 inches (43.2 - 55.9 cm) long, 1 lb 8 oz - 4 lbs (.7 - 1.8 kg)
- shallow to moderate depths
- In the mid-1800s, whitefish were abundant in Lake Erie. For instance, in 1885, 1,249,000 lbs (566,536.9 kg) were brought into Ohio ports. By the mid-1900s, the whitefish had become rare, and by 1950 only an occasional stray was caught. There is presently no current documentation of whitefish spawning in the Western Basin of Lake Erie, though they still exist in the area.



Coregonus clupeaformis
(Lake Whitefish)

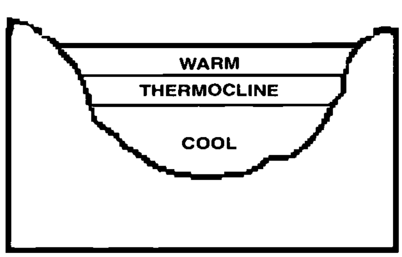
Life Support for an Aging Lake

Some of the natural processes that lakes undergo are likely to be intensified with global climate change. This set of activities explores those possibilities.

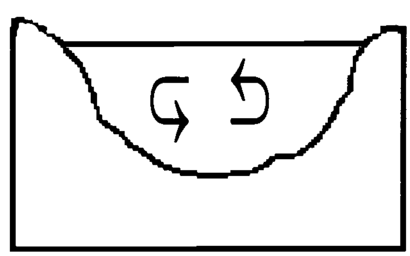
Stratification. During summer months, deep lakes in the world's temperate zones experience a process called stratification. This happens when the sun's rays penetrate surface waters during the early summer months and create a warm upper zone in the lake. At the bottom of the lake, the water remains cooler. These two zones are separated by a narrow transitional zone called the *thermocline* or *mesolimnion.* The thermocline, where water density changes rapidly with depth, prevents the layers from mixing and separates the bottom layer from its major source of oxygen — the air. Shallower lakes (less than about 12 meters or 40 feet) can usually get mixed by the wind so that the strata do not remain. In deeper lakes, however, the bottom–dwelling organisms may exhaust their summer supply of oxygen. When this happens and the oxygen becomes depleted, the affected area is thought of as *anoxic* (without oxygen). In this case, organisms have to relocate into other parts of the lake. Otherwise, they will die before the fall turnover replenishes the lake bottom's supply of oxygen.

Scientists predict that if global warming occurs, the Great Lakes could have longer periods of stratification. Lake Erie is the warmest, shallowest and most biologically productive of the Great Lakes. Stratification could last two to four months longer in Lake Erie's Central Basin than presently occurs. Changes in wind patterns could also have an effect on the depth at which stratification occurs in the lakes. Increased winds will mix oxygen and nutrients in the upper layer more thoroughly and deeply, thus forcing the thermocline to form deeper during the stratified months, leaving less cool bottom water. The same processes would unfold in all the Great Lakes, but for all except Erie their depths would protect them from becoming anoxic.

Summer Lake Profile



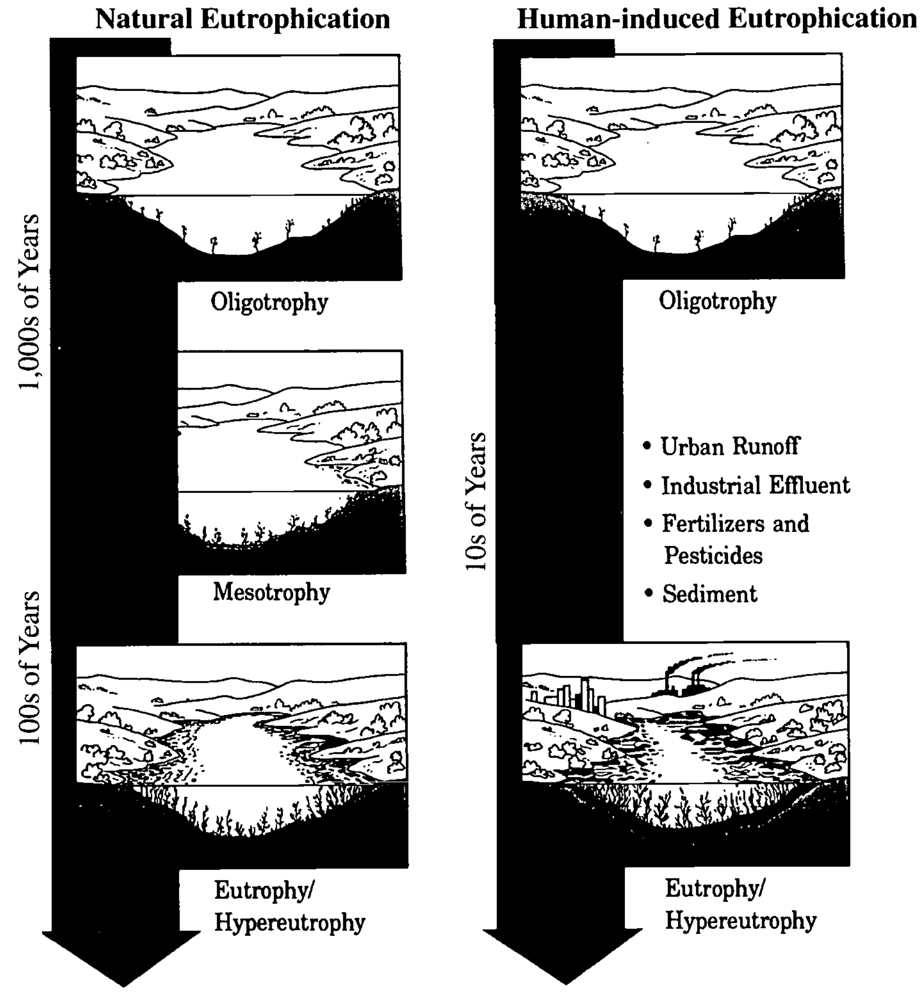
Fall Lake Profile



With predicted warmer temperatures, bacterial activity would increase in the lake, intensifying the demand for oxygen. Also, higher evaporation rates and altered precipitation patterns could cause lake levels to drop, and pollutants to become more concentrated. *Algal blooms*, proliferations of blue–green and green algae, would occur, further accelerating the aging process of the lake.

Aging process. Lakes age naturally through a process called *eutrophication*. Over time, many *oligotrophic* (cold, deep, barren) lakes and ponds gradually become *eutrophic* (warm, shallow, fertile). If there is not a sufficient flow and overturn of water to flush out accumulating sediments and organic material, the process of aging ends at *senescence*, in which lakes become wetlands, then moist lowlands, and then dry land.

Human activity can speed up the rate of eutrophication, thus shortening the life span of a lake or pond. This *cultural eutrophication* is of great concern in the case of Lake Erie. The lake's biological diversity and productivity are threatened by *nutrient loading* and siltation from agricultural runoff. The Eastern and Central Basins of Lake Erie are especially vulnerable to cultural eutrophication because they are of sufficient depth for stratification to occur. These two basins then become *anoxic*, with no dissolved oxygen in the lower layer.



Deposition of Air Pollutants in the Great Lakes. 1994. USEPA

When nutrients such as phosphates are "loaded" into a lake, algae populations rise dramatically. This greatly accelerates the natural aging process of the lake because the extensive growths eventually die and sink. In breaking down the extra organic material, decomposers on the lake floor decrease the oxygen levels in the lower layer. Because the oxygen is not replaced during the summer stratified months, the dissolved oxygen levels plummet, causing anoxic "dead" areas at the bottom of the lake. For this reason, many states now have laws concerning the amount of phosphates that laundry detergents and other products can contain.

Although humans cannot prevent or reverse natural eutrophication of the Great Lakes, we can, through proper management, reduce the effects of our own actions. By mitigating cultural eutrophication, we can give life support to one of our natural treasures.

Activity A: What happens to *Euglena* populations when temperature and/or nutrient levels increase?

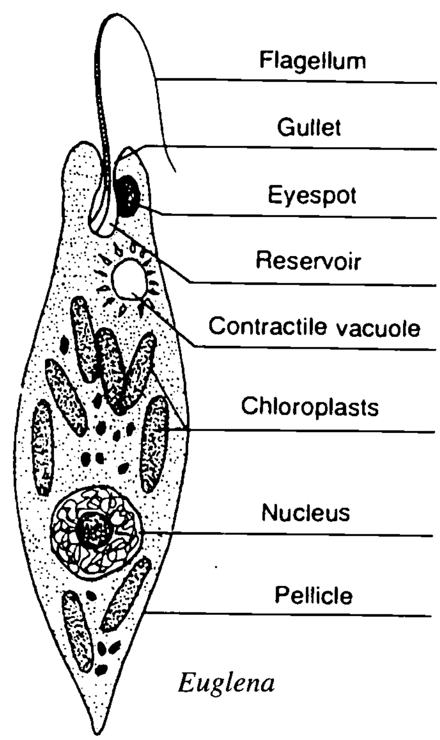
The temperature of water is a very important aspect of water quality and affects many of the physical, chemical, and biological characteristics of a body of water. Temperature is a factor in:

1. The amount of oxygen that can be dissolved in water. Cooler water can hold more dissolved oxygen than warmer water. Soda pop, for instance, goes flat quickly when it is warm, because it cannot hold as much dissolved gas in the solution as it can when it is cold.
2. The rate of photosynthesis by algae and larger aquatic plants. These organisms become more active as temperatures warm. If the temperature gets too hot, however, it can harm their population.
3. The sensitivity of aquatic organisms to toxic wastes, parasites, and disease. Increased temperature increases sensitivity.

Phosphates and nitrates are nutrients for many microscopic organisms. When these nutrients are plentiful, the populations of algae and bacteria grow very rapidly. This activity will examine the relationship between temperature, nutrient levels, and the population growth of *Euglena*.

Euglena are one–celled, photosynthetic bacteria. Light is necessary for them to photosynthesize, and they use an *eyespot* to help them find light. At right is a diagram of *Euglena* and the structures that can be seen through a microscope.

The pellicle is a flexible outer covering. The flagellum propels the *euglena* through the water. It is used much like the propeller of an airplane. The *euglena* can also "crawl" by changing the shape of its body (pulling it together in a ball and pushing rounded end forward). The eyespot contains red pigment and is used to find the light needed for photosynthesis. *Euglena* make their own food (as do plants) by photosynthesis, and they can also absorb nutrients from the environment.



Euglena

Objectives

After completing this activity, students will be able to:

- explain how increased water temperature affects *Euglena* population growth.
- explain how nutrient loading affects *Euglena* populations.
- compare the effects of phosphorus on *Euglena* population size at different temperatures.
- hypothesize a possible impact of global warming on aquatic life in the Great Lakes.

Earth Systems Understandings

This activity focuses on ESU 1, 2, 3, 4, and 5. See p. VIII for explanation.

Scenario Reference

#7, Will it (global change) speed eutrophication in the Great Lakes?

Materials

Each group of two to three students will need:
- 4 test tubes, marked #1, #2, #3, and #4
- 4 well slides with cover slips
- 1 medicine dropper
- 1 stirring rod
- Notebook or journal
- 4 cotton balls
- Microscope

Classroom will need:
- 2 thermometers
- 1 heating unit
- 1 large glass container (to hold half of the test tubes)
- Tap water
- *Euglena* culture
- Source of Phosphates/Nitrates [Each class group could try a different source such as bone meal, Vitamin B12, plant fertilizer, powder laundry detergents with phosphates, or other substances that students predict would cause nutrient loading in a lake.]

Notes

2. It is not essential to use 50 percent tap water / 50 percent *Euglena* mixture. Keep in mind however, that the higher the concentration of *Euglena*, the sooner differences between test tubes will be evident.

3. Test tubes #1 and #2 could also be gently stirred in order to keep "stirring" from becoming an extraneous variable.

6. All the slides should theoretically have approximately the same number of *Euglena* on the first day.

PROCEDURE

Step 1: Establishing the experimental conditions

Students will set up a pair of controlled experiments to test the effects of temperature and nutrients on population growth of *Euglena*.

Preparation. (1) Obtain a culture of *Euglena* from a biological supply catalog and study the optimal growth requirements recommended by the supplier. (2) Allow 2 quarts of tap water to sit out uncovered overnight so that it will become room temperature and any chlorine in it can escape. Tap water contains some nutrients which the *Euglena* can use to grow.

1. Each lab group should fill four test tubes "halfway" with the tap water. Be sure tubes are numbered 1–4.

2. Add *Euglena* culture to each of the four test tubes until it reaches the designated "full" mark.

3. Each group should add 1 drop (or small pinch) of their nutrient substance to test tubes #3 and #4 and stir gently. A very small amount is all that is necessary. These test tubes will represent a nutrient-loaded lake.

4. Students hold all four of the test tubes against a white background. Record any interesting observations, particularly regarding water clarity, color, or odor.

5. Using a clean medicine dropper, students put a sample drop from each test tube onto separate well slides (samples should be taken from just under the surface of the liquid) in order to inspect the *Euglena*. Be sure to clean the dropper thoroughly between uses.

6. Students examine these slides with a microscope and make general observations on water clarity, color and *Euglena* populations. Record these and any other observations for each test tube. Depending on the density of the *Euglena*, it may be difficult to count them accurately but students should try to determine whether any of the slides have noticeably more or less *Euglena* than the others.

7. Each of the test tubes should be covered to prevent evaporation. Cotton balls work well for this.

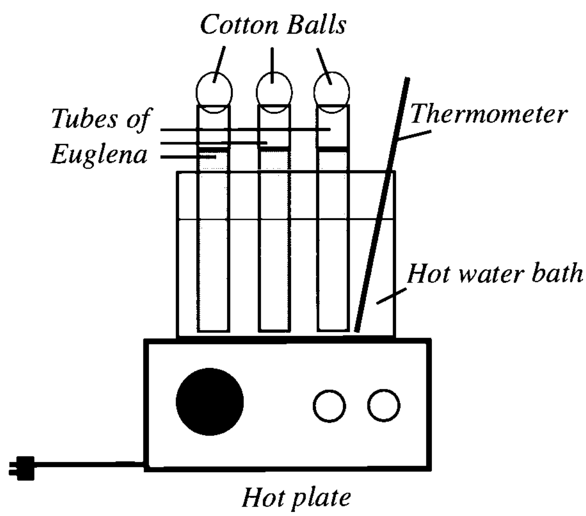
8. Test tubes #3 and #1 (one with phosphates and one without) should be placed where they will remain at room temperature. This is to resemble the normal Lake Erie high temperature (approximately 22° C).

9. Test tubes #2 and #4 (one with phosphates and one without) should be kept at a temperature between 30° C and 32° C. It is important that this temperature remain fairly constant. If the *Euglena* become too hot, they will die.

Temperatures for this activity were chosen not because they reflect expected lake temperatures, but so that the experiment does not take too long and has a chance to show detectable results.

Because *Euglena* are photosynthetic bacteria, it is important that all the test tubes have similar lighting conditions. Have students brainstorm different factors that might confound the results: Are the only differences between the test tubes the presence of nutrients in some and the higher temperature in some?

If a climate control unit is not available, one way to heat these test tubes is to put all the tubes labeled #2 and #4 in one larger glass container and put it over the heating mechanism. Water should be added to the larger container in order to keep heat dispersed around the test tubes. Place a thermometer in the water surrounding the test tubes to keep track of the temperature. Each student group should remember to mark their test tubes so that they will be able to distinguish which are theirs.



Hint

In order to keep this temperature from fluctuating, set the larger container (with the water and thermometer in it) over the heater a few days in advance so that any necessary adjustments in the heating level can be made before the test tubes with *Euglena* are added.

Step 2. The next several days

For the next three or four days, students should make brief daily observations on the temperature, color, clarity, and odor of their four test tubes and record these findings in their journal.

Test Tube Conditions

	Room Temp.	Increased Temp.
No Nutrients Added	#1	#2
Extra Nutrients Added	#3	#4

Answers

a. Answers will vary. Theoretically, after a few days, test tube #4 (with additional heat and phosphorus) would be the greenest, and test tube #1 (no heat and no phosphorus) would be the least-green. Eventually, however, the rapid growth in test tube #4 will quickly deplete the oxygen and result in a rapid population decline in that test tube. When this happens, test tube #1 should contain more *Euglena* than test tube #4 (at this point test tube #4 represents an anoxic lake).

b. Euglena need nutrients and oxygen to live, so they may congregate around sources of these things. Their eye spots help them to orient themselves towards light so that they can photosynthesize. It may also be possible that the *Euglena* move away from concentrations of harmful substances in the water.

c. Answers will vary. Phosphorus causes increased *Euglena* growth; this should have been most evident in the warmer test tube.

d. Increased temperature should initially cause an increase in *Euglena* activity.

Step 3. Approximately Day 5

This is a time to make more detailed observations. The greener the color, the more *Euglena* activity is occurring.

1. Hold all four of the test tubes against a white background and answer the following questions:

   a. What differences are there in color? Are some solutions greener than others? Which is the greenest? What conditions appear to cause the quickest *Euglena* growth?

   b. Do the *Euglena* appear to be congregated in any area of the test tube? Why might this be?

   c. Does the presence of phosphorous appear to make a difference to *Euglena* growth? If so, what has happened? Is the effect the same for both test tubes containing phosphorus?

   d. Does the increased temperature appear to make a difference to *Euglena* growth? If so, what has happened? Is the effect the same for both test tubes with increases in temperature?

2. Use the medicine dropper to take a sample from the greenest test tube solution. Put it on a well slide and study it under a microscope. Repeat this step with the test tube with the least amount of green. Examine the differences between the two. Does one seem to have obviously more *Euglena* than the other? Record any findings or observations.

At this time, Step 2 can be repeated if that is deemed appropriate. Population differences may not be noticeable for a week or two.

Step 4. The Last Day

1. Have the students rank the test tube solutions from the greenest to the least green.

   a. How can these results be explained?

2. If different sources of nutrients were used, students groups compare how *Euglena* reacted to the various sources.

   b. Which source caused the quickest growth?
   c. Which caused the least amount of growth?
   d. Did any of the sources appear to have an immediate negative impact on the *Euglena* colony?
   e. How does human behavior cause these various sources of "nutrients" to enter the water system?

a. Phosphorus and increased temperature will cause an increase in *Euglena* growth, but this growth will be followed by a massive die–off when the population becomes so large that dissolved oxygen levels become depleted. In this sense, test tubes #1 and #4 (with nutrients) will experience rapid population growth followed by large die–offs, while in the other (nonnutrient loaded) tubes, the populations will grow slowly and eventually die off much more slowly.

b.-e.
Answers will vary depending on the nutrient source used.

REVIEW QUESTIONS

1. Summarize the experimental results: What effect do phosphates and other nutrients have on *Euglena* populations? How do nutrients (phosphates and nitrates) and increased temperature affect the *Euglena*?

2. Hypothesize about the ecosystem effects of temperature and increased nutrients that could result from global change in the Great Lakes region.

1. Initially, *Euglena* colonies thrive on phosphates, their populations bloom and they use lots of oxygen. As their activity increases, the amount of dissolved oxygen decreases. This will eventually cause a large die–off in the population. Both nutrients and higher temperatures increase *Euglena* activity. The heat makes them more sensitive (receptive) to the added nutrients. At first, the populations in these conditions should do very well. Ultimately however, test tube #4 will have the least amount of *Euglena*.

2. If other microorganisms are affected like the *Euglena*, the base of the food chain could be disrupted, with disastrous ecosystem effects. Students may want to read about Lake Erie's eutrophication problems in the 1960s and 1970s as an example of what increased nutrients can do. (See Chapter 14 of *The Great Lake Erie*, from Ohio Sea Grant.)

EXTENSIONS

1. Keep one test tube with added nutrients and one test tube without added nutrients in a corner of the classroom for several months to see what effect the nutrients have over a longer period of time.

2. If this activity is done with a hay infusion instead of a pure culture of *Euglena*, it may be possible to see a succession of how various microorganisms respond to the changing environment.

3. Have students design an experiment in which they investigate the effect of temperature and/or nutrients on another aquatic organism such as *Gammarus* (scuds) or snails.

Activity B: How does an increased amount of lake life affect dissolved oxygen levels?

Dissolved oxygen in water is vital to the life of the plants and organisms living in it. The amount of dissolved oxygen is decreased by the activity of algae, bacteria, and other microscopic organisms as they respire and when they decompose after death. This activity visually illustrates the absence of dissolved oxygen created by the activity of organisms in the water.

Oxygen levels in water are replenished when the water comes into contact with air. When lakes become stratified, the water on the bottom does not mix with the "oxygenated" water at the surface for several months at a time. For this reason, it is important that the organisms at the lower levels do not completely deplete their supply of oxygen before the fall turnover brings a fresh supply of water to the bottom of the lake. When the oxygen becomes depleted, an *anoxic* dead area is created in the lake.

Yeast is a fungus that germinates and multiplies in the presence of a food source and dissolved oxygen. In this activity, yeast population growth is used to simulate the effects of all kinds of aquatic life on the amount of dissolved oxygen in water. The greater the population, the more oxygen is used in respiration and decomposition.

Earth Systems Understandings

This activity focuses on ESU #4 (interactions) and #5 (change through time). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#7, Will eutrophication be affected?

Materials

- 2 200-ml glass containers (or 2 2–cup measures)
- 1 spoon (this will work better than a stirring rod)
- Methylene Blue (.3% aqueous solution)
- Dropper
- 1 package of activated dry yeast
- Nonfat dry milk to make approximately 2 cups

Objectives

At the end of this activity, students should be able to:

- Describe how the amount of dissolved oxygen changes as the activity of aquatic organisms increases.
- Analyze how lower lake levels can make anoxia more likely.

PROCEDURE

1. Using lukewarm water, mix up enough nonfat dry milk to fill the two 200 ml containers almost to the top (200 ml is about 7/8 cup).

2. Once the milk is in the containers, add two drops of Methylene Blue (.3% aqueous solution) to each container.

3. Add the yeast (one package) to one of the containers and stir until the yeast dissolves. (This may be somewhat difficult, because the yeast will tend to clump together.)

4. After about 30 minutes note the difference of the color in the containers. Some change should be noticeable immediately. What does the color change indicate is happening?

2. Methylene Blue is an indicator solution for oxygen; the blue color indicates the presence of dissolved oxygen.

4. The container with yeast should continue to lose its blue color until there is not a trace of blue. The yeast uses oxygen, causing the blue color of the oxygen indicator to disappear.

REVIEW QUESTIONS

1. Develop a flow chart or concept map to demonstrate how oxygen is added to and removed by physical and biological processes in lakes. Include an indication of what prevents oxygen from being replenished in lower lake levels during the summer.

2. Hypothesize about why aquaria often have systems that cause air to be released in the water. If Lake Erie had a giant aquarium "bubbler" during the summer, what effect would this have on the oxygen levels in the lake?

3. What actions could humans take to help prevent oxygen depletion in lakes?

1. Answers will vary, but some critical parts that should be included are: Oxygen levels are replenished by contact with air and by photosynthesis. During the summer, the sun's rays penetrate surface waters and create a warm upper zone in the lake. Below is a cool lower layer, separated from above by a narrow transitional zone called the *thermocline*. The thermocline separates the bottom layer from its major source of oxygen — the air. Oxygen is removed from water by respiration and decomposition.

2. The bubbling action in an aquarium helps the water and oxygen to mix, because it creates a situation in which more surface area of water comes into contact with air. It also keeps the water in a tank in motion so that it mixes and the oxygen is dispersed throughout the tank.

   If Lake Erie had a giant "bubbler," the lake would not become stratified, because the water would be forced to mix and oxygen would be supplied to the lower levels. Of course, such a machine would also greatly disrupt the delicate ecosystem of the lake.

3. Humans could reduce the amount of nutrients that are dumped into lakes (fertilizers, sewage, run-off). These nutrients cause increased activity in algae and bacteria, which reduces the oxygen in lakes.

Estuary Values and Changes

Along the shores of the Great Lakes are numerous marshes and estuaries. These wetlands support a great diversity of plant and animal life. Abundant aquatic and terrestrial organisms use areas either on a temporary or permanent basis. Unique wetland habitats support a greater variety of plant and animal life than any other area of equal size in the region.

Estuaries are not easily defined. They have traditionally been characterized as the area where fresh water meets the sea and water levels rise and fall with the tides. Estuaries, however, can be more than just an aquatic interface between fresh and salt water. In a larger meaning, they are the part of the mouth of a stream in which the water level is influenced by the lake or sea into which the stream flows. In this case, they occur where rivers meet freshwater lakes. Many different habitats — marshlands, open water, sand beaches, upland forests, even cities and agricultural fields — can merge at these unique areas.

Terrestrial and aquatic vegetation serve several functions in an estuary. Emergent aquatic plants filter out large quantities of nitrogen, phosphorus, pesticides, and silt. Subsequently, some of the nutrients and toxins are taken up by the root systems of these aquatic plants. Without estuaries and marshes acting as a natural buffer zone, even greater quantities of pollution would enter the Great Lakes.

Additionally, plants provide a food source for herbivores and detritus feeders (organisms that feed on dead materials), which are the base of the lake food web. The thick layers of foliage in an estuary provide protective breeding and nursery grounds for fish and other aquatic animals. Finally, estuaries reduce the harmful flooding effects of storms in the Great Lakes watershed by absorbing large quantities of storm water and then slowly releasing the water into the lakes.

Global warming is predicted to increase lake water evaporation and cause lake levels to lower. If this happens, many estuaries could lose their distinct identities. Only those located where the conditions are compatible with new shorelines will remain.

The following activities explain some of the beneficial environmental functions wetlands contribute and what may happen to some estuaries if global warming occurs.

Activity A: What happens when nutrients enter a lake?

How do phosphorus and nitrogen get into the Great Lakes? One way is from water runoff. Rainwater falling on farm fields, parking lots, roads, and backyards flows into creeks, streams, and rivers. The rainwater carries soil, fertilizers, and pollution it has washed from the land. You have probably seen how much more water creeks carry just after a storm and how muddy the water looks. Eventually, all this water runs into the lakes, bringing nutrients and other chemicals with it.

Earth Systems Understandings

These activities focus on ESU #2 (stewardship), 3 (science methods and technology, and 4 (interactions).

Scenario Reference

#6, What are the Implications of low Water Levels in Great Lakes Estuaries?

Materials

- nitrate and phosphate data charts
- map of Old Woman Creek
- graph paper
- pencils
- glass jar with lid
- soil

Objectives

- Describe the characteristics of oligotrophic and eutrophic lakes.
- Explain the effects of nutrient loading on lake habitats.
- Define nutrients as a limiting factor in lake habits.
- List sources of nutrient inputs to Lake Erie.
- Explain how wetlands can improve water quality.

Procedure

A. Look at the map of Old Woman Creek. With your pencil, trace the path of the creek, starting at the point marked **A**.

1. Where does the creek go? Does water from the creek flow into Lake Erie?

B. On the same map, look at the land that is surrounded by the dotted line. All the land within this line is the watershed of Old Woman Creek. Water from this land runs off into Old Woman Creek, then through Old Woman Creek Estuary, before reaching Lake Erie. A watershed is all of the land drained by a creek, stream, or river.

2. Are there any roads or farms in the Old Woman Creek watershed? How might these affect the water entering the creek?

C. The smaller inset map shows places in the estuary where scientists have tested the creek's water to see how much phosphorus and nitrogen it contains.

3. How many test stations are located in or near the estuary? Which station is closest to the lake? Which is closest to where the creek enters the estuary?

D. On a piece of graph paper, graph the concentration of phosphorus at Station 1 in the estuary for each day after the storm from day 1 to day 11. Use the data from the Nitrate and Phosphate Data Chart (See Figure 2).

4. At Station 1, how many days after the storm were phosphorus levels the highest? When were phosphorus levels the lowest? How can you explain this?

E. Now graph phosphorus concentrations at Stations 3 and 6 for each of the days after the storm. If you use the same sheet of graph paper to draw this graph, be sure to label your lines Station 1, Station 3, and Station 6.

5. What day did peak (highest) phosphorus concentrations occur at Station 3? What day did phosphorus peak at Station 6? Can you explain why peak concentrations of phosphorus occurred later at Station 3 than at Station 1 and later at Station 6 than at Station 3?

F. Look at the data showing nitrogen concentrations at Stations 1, 3, and 7.

6. On what day do the peak concentrations of nitrogen occur at each station? Does it seem that the peak nitrogen concentrations are following the same kind of pattern that peak phosphorus concentrations showed?

7. By day 9, have the peaks in phosphorus and nitrogen concentrations occurred at all seven stations?

G. On a new sheet of graph paper, make a graph of the concentration of phosphorus at each station in the estuary on day 9.

8. For day 9, at which station are phosphorus concentrations the highest? At which station are they the lowest? What might this suggest about the action of the estuary on water flowing through Old Woman Creek?

H. On the same graph paper you used in Step G, graph the concentration of nitrogen at each station in the estuary on day 9. (Note that N and P are not measured in the same units. This is consistent with the data.)

9. At which station are nitrogen concentrations the highest? At which station are they the lowest?

Answers

1. The creek flows north into Old Woman Estuary and then empties into Lake Erie.

2. U.S. Highway 6, Ohio Routes 2 and 61, and other roads run through the watershed. There are also several farms. Runoff water from roads and farms will carry pollutants and fertilizers.

3. There are seven water test stations in or near the estuary. Station 1 is closest to where the creek enters the estuary. Station 7 is near the entrance of the creek into Lake Erie.

4. Phosphorus levels were highest one day after the storm and lowest 11 days after the storm's onset. At day 1, a lot of runoff water was entering the estuary. This water contained high concentrations of phosphorus. By day 11, there was much less runoff from the storm. Thus, fewer nutrients were being carried into the estuary.

5. Peak phosphorus concentrations occurred on day 3 at Station 3 and on day 4 at Station 6. Stations 3 and 6 are located further downstream in the creek. Water from the creek reaches Station 1 first, then Station 3, then Station 6. Nutrients such as phosphorus being carried by the water reach these stations in the same order.

6. Peak nitrogen concentrations occur at Station 1 on day 4, at Station 3 on day 6 and at Station 7 on day 8. Nitrogen concentrations are following the same general pattern as phosphorus concentrations. The peak concentration of nitrogen occurs at upstream stations before occurring downstream.

7. By day 9 the peaks in phosphorus and nitrogen concentrations have occurred at each of the stations.

8. Phosphorus concentrations on day 9 are highest at Station 1 and lowest at Station 7. This suggests that nutrients are removed as the water passes through the estuary before entering Lake Erie.

I. Fill a jar half full of water. Put a handful of soil into the jar. Shake the jar so that the water and soil are moving quickly and get mixed together. You have created muddy, stirred–up creek water in your jar. Wait a few minutes for the water to slow down and the soil to settle to the bottom of the jar. The water in the jar now is more like water in the estuary.

10. Where do you think estuary water will be the muddiest? Where will it be the clearest? What is one reason why phosphorus and nitrogen concentrations are lower at Station 7 than at Station 1?

11. The estuary has many plants growing in it. How might the plants affect the amount of nutrients reaching each station?

J. Estuaries and other wetlands act as sinks and sponges of nutrients. Nutrients associated with mud settle out of the creek water and sink to the bottom of the estuary as the water passes through the estuary. At the same time, nutrients are taken up by estuary plants for growth.

12. How might an estuary's action as a sink and sponge for nutrients affect the lake into which the creek empties?

Answers

9. Nitrogen concentrations are the highest at Station 2 and the lowest at Station 7. Forms of nitrate and phosphate can be either dissolved in the water, suspended as particles, or attached to sediments.

10. Following a storm, creek water is muddy from carrying soil and nutrients, and it is moving very quickly. As water flows through the estuary, its movement is slowed. Much of the sediment, soil, and nutrients in the water settles out as the water slows down. Thus, the water reaching downstream stations is clearer and has lower concentrations of nutrients than the water flowing through the upstream stations.

11. To explain the decrease in the phosphorus and nitrogen concentrations from Station 1 to Station 7, try the following: Plants in the estuary need phosphorus and nitrogen as nutrients to grow. Thus, plants in the estuary take up and use phosphorus and nitrogen from the creek water as it passes through the estuary. The plants filter out nutrients that they need from the creek water. This is another reason why fewer nutrients reach the downstream stations.

12. Because of the estuary's filtering action, water entering the lake will contain fewer nutrients than it otherwise would. Many of Lake Erie's water problems result from too many nutrients entering the lake. Estuaries may improve water quality in the lake by reducing the nutrients entering it.

Extension

1. *Lake Layers: Stratification in the Great Lakes*, OEAGLS* activity number EP-28, includes two activities related to nutrients in the lakes and water quality. Students simulate the stratification of water that occurs in lakes during the summer using an aquarium. On several maps of Lake Erie, they measure the lake area that has become anoxic (lacking oxygen) since the 1930s and relate this to nutrient inputs.

2. *The Estuary: A Special Place*, OEAGLS activity number EP-16, includes activities designed for further investigation of the Old Woman Creek Estuary. Students study the characteristics of an estuary using a computer map and a transect line and analyze illustrations of plankton samples to observe how estuaries serve as nurseries for lake fish.

* Oceanic Education Activities for Great Lakes Schools, available from the Ohio Sea Grant College Program, The Ohio State University, 1314 Kinnear Rd., Columbus, OH 43212, (614) 292-8949.

Review Questions

1. How do estuaries act as "sinks" and "sponges" to improve the quality of water going through them and reaching the lake?
2. How do the characteristics of oligotrophic and eutrophic lakes differ in terms of nutrients? (Hint: Review Scenario #7.)
3. What happens when nutrients are readily available in, or are added to, a lake?
4. What is a limiting nutrient? What nutrients are usually limiting in a lake?
5. What are some of the human produced sources of nutrients entering the lakes?

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Answers

1. Plants in the estuary take up and use the nutrients they need from the water passing through the estuary, thus acting as sponges. As water flows through the estuary, its movement is slowed. Much of the soil and nutrients in the water settle out as it slows down. Thus, the wetlands act as nutrient sinks. Estuaries may improve the water quality in the lake by reducing the amount of nutrients entering the lake.

2. Oligotrophic lakes have low nutrient levels. They are often deep and have small surface areas. Plant production is low, and the water is clear. Eutrophic lakes are rich in nutrients. They are often shallow and have large surface areas. Plant production is high, and the water is murky.

3. The nutrients act as a fertilizer, allowing plants to grow. Adding nutrients increases plant growth, especially the growth of algae. The algae may be green or blue–green depending on what nutrients are available.

4. Nutrients are needed for plant growth. The nutrient that is missing or available only in low levels is the limiting nutrient, because it limits or controls the amount of plant growth. Phosphorus and nitrogen are usually the limiting nutrients in lakes. These are often in the form of PO_4^{-3} (phosphate) and NO_3^{-1} (nitrate) ions.

5. Nutrients enter the lake from runoff from farms, parking lots, roads, and yards. This runoff contains soil, fertilizers, and pollution it has carried from the land.

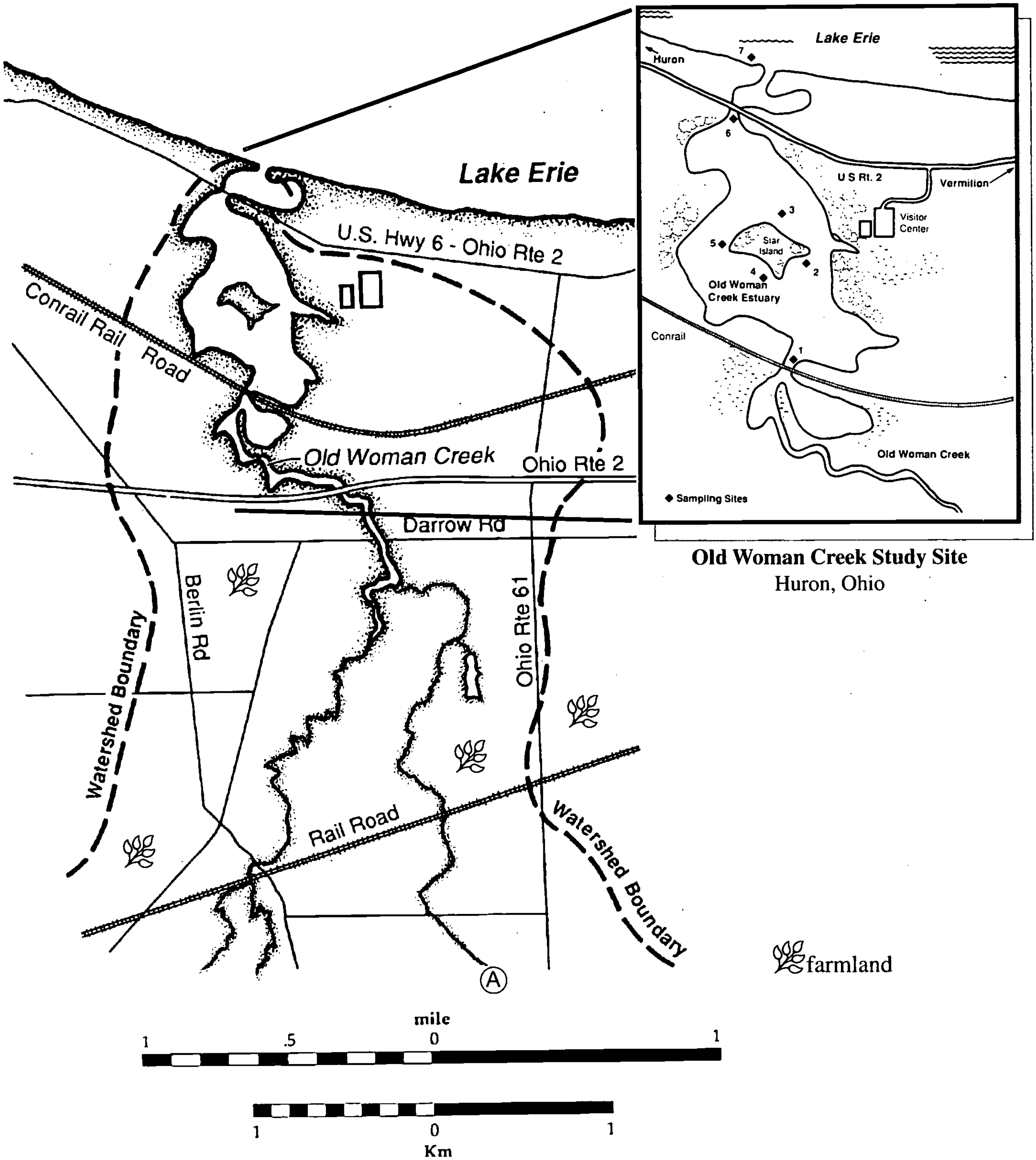


Figure 1. The Old Woman Creek watershed with water test stations

Nitrate and Phosphate Data Chart

		DAY AFTER STORM (May 1985)										
Station	**Nutrient**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	**P (ppb)**	283	82	70	94	60	32	40	49	40	35	30
	N (ppm)	6.5	6.9	9.7	12.4	10.5	9.5	7.8	6.5	6.6	6.5	6.6
2	**P**	104	97	79	79	50	35	21	12	10	7	3
	N	1.5	3.3	6.1	8.7	9.0	10.1	9.0	8.0	7.7	6.5	5.9
3	**P**	9	41	67	66	32	19	15	10	9	8	7
	N	.4	1.9	2.8	7.6	8.4	9.9	8.0	6.8	5.8	4.1	2.3
4	**P**	9	7	35	28	19	11	11	10	7	5	3
	N	.2	.3	2.4	3.3	5.1	8.8	8.7	8.4	6.5	4.8	2.2
5	**P**	8	11	10	22	20	16	12	10	6	3	2
	N	.2	.8	.6	2.6	4.9	9.7	7.8	6.9	6.0	4.1	2.3
6	**P**	9	5	10	26	19	11	10	10	8	6	5
	N	.5	.5	2.0	3.4	3.4	3.4	3.3	3.3	3.0	2.7	1.7
7	**P**	5	2	1	6	5	3	3	3	2	2	2
	N	.9	1.0	1.1	1.4	1.6	1.7	2.0	2.1	1.7	1.5	1.2

(Data for underlined dates were interpolated from those before and after the date. P and N were not measured directly on these days.)

Figure 2. Changes in nitrate and phosphate concentration in water at sites along Old Woman Creek for a period following a storm.

Activity B: How does the estuary serve as a nursery?

Among their many functions, wetlands serve as important protective breeding and nursery grounds for fish and other aquatic animals. Aquatic animals such as plankton establish themselves as essential links in the food chain by providing food sources for fish populations. However, the threat of increasing water temperatures as the result of global warming may have severe effects on the aquatic community. Plankton and fish may not be able to adapt to a temperature increase, causing a deficiency in food supplies for organisms in the upper food chain.

Earth System Understandings

This activity focuses on ESU #3 (science methods and technology), #4 (interactions), and #5 (change through time). See p. VIII.

Scenario Reference

#6, What are the Implications of Low Water Levels in Great Lakes Estuaries?

Materials

- "plankton samples" in Figures 3 and 4
- ring from a canning jar (wide mouth, having an inside diameter of 7.4 cm)
- pencil

Teacher's Note

Have the students practice the technique and calculations for the E "population" on one or two printed pages before going on to the plankton pages.

If for some reason you wish to use the regular-mouth jar rings, having the i.d. of 5.7 cm, use 25.5 cm^2 for the area in Step 2, and use 16 for the multiplication factor in Step 3.

In sampling for Figures 6 and 7, students will often have organisms that are only partly visible in the ring. Follow the general rule that if one half of the organism or more is visible, the students should count that as one whole organism. For algae clumps, it is probably most accurate to count every strand of algae as a different organism, rather than counting clumps or clusters.

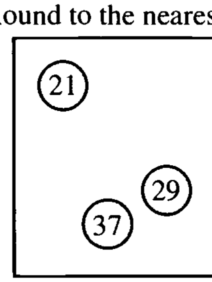
Objectives

- Describe the methods used by ecologists to sample populations of plant and animal life in the water.
- Give a general description of the plant communities that are found in different depths of water in an estuary.
- Explain how plant communities are important to animal life in the estuary.
- List the types of organisms that are found as plankton in an estuary.
- Predict the effects of some human and environmental forces on conditions in an estuary.

Procedure

A *sample* is one method that ecologists use to examine a population without observing and counting every organism. A sample can be taken by randomly choosing an area of a certain size and counting all the organisms present. To see how this works, do the following:

1. Take a canning jar ring and drop it anywhere on this page. Count the number of times the letter **E** appears in the circle.
2. Repeat this two more times. Add up your three counts and divide the total by 3. This gives you the average number of Es in an area of 43 cm^2 (the area inside the ring).
3. To estimate (make an educated guess about) the total number of Es on the page, multiply your average by 9.5, since the page is about 9.5 times as big as the area inside the circle. Round to the nearest whole number.



$$\begin{array}{r} 21 \\ 37 \\ \underline{+29} \\ 87 \end{array} \qquad 87 / 3 = 29 \quad 29 \times 9.5 = 276$$

Now let's pretend that a jar of water has been collected from the Old Woman Creek estuary. It was collected in a special way. A plankton net (Figure 1: student–made plankton net) was towed behind a boat for about five minutes. The net had a jar at the end that caught all the tiny organisms in the water, while the water escaped through holes in the net.

The jar of water has thousands of organisms in it. You can tell they are there because they keep the water churned up in the jar, but you can't see them well enough to tell what they are. You need a microscope.

Figures 3 and 4 show some of the animals you might see through the microscope. Figure 3 is from a plankton sample collected in May, and Figure 4 is from an August sample. Look at the organisms shown and compare them to the pictures in the chart on your worksheet. Be sure you tell which are algae, zooplankton, and fish larvae.

4. Repeat the sampling method you used for the letter e, but this time sample the organisms in Figures 3 and 4. It is best if you actually trace your sampling circles on Figures 3 and 4. This will make it easier for you to record on the chart and still not disturb your sample (move the ring). Also, you can come back to your samples and recheck them as the need arises. Record your results on the worksheet.

Figures 3 and 4 are based on actual plankton samples collected along the Lake Erie shore. Both the numbers and types of organisms are therefore fairly accurate examples of what may be found in the Old Woman Creek area.

Hopefully, those of you who said, "but why not just count all the Es?" on the **E** sampling page can see better why scientists frequently resort to sampling techniques. (Imagine a scientist trying to count all the individual organisms in the estuary!)

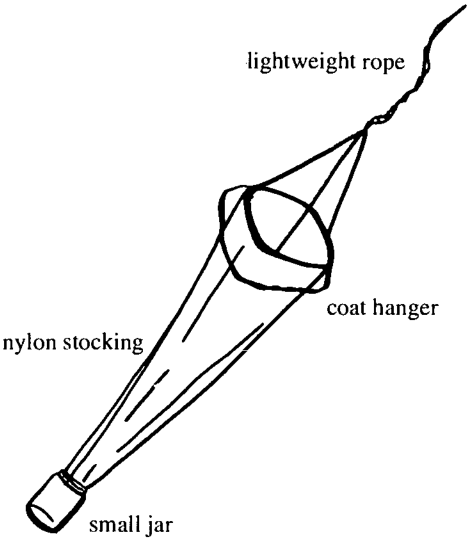


Figure 1. Student-made plankton net

Hint

In the table on the worksheet, the first type of algae listed is Diatoms. When recording your sample, count both kinds shown, and list them together as Diatoms. Do the same for the green and blue–green algae. The number you write will be a total for both species in each category. In the case of the zooplankton, only one species of each of the different groups is shown.

Answers to Procedure

For most of the following, results would probably be more accurate if the entire class would pool its information.

A. 1. Spring
2. Summer
3. Spring
4. Summer
5. Spring
6. Spring
7. Summer

B. Summer water is warmer. Sheepshead and white bass appear to require warmer water for spawning.

C. Spawning times could be related to the availability of food for the larvae. There may also be temperature tolerances of the fish to be considered, and some fish are sensitive to overcrowding. Another reason could be to keep species from interbreeding. Discuss all possibilities that students suggest.

D. 1. Plants could be killed. Plant plankton would probably increase in number up to a certain water temperature. Zooplankton would probably be killed. Fish that depend on warmer water temperatures to determine their spawning time might spawn earlier than usual. If the temperature got too high, some fish would not enter the estuary at all. Fish larvae might have more algae to eat, but excess heat could kill both eggs and larvae. The food supply would be affected.

D. 2. The drop in the water level could cause the destruction of the water plants rooted there. With less water flowing into the estuary, its ability to serve as a buffer is decreased.

Answers to Review Questions

1. Population sampling is the method that ecologists use to find out how many and what kinds of organisms are in a community. A portion of the organisms in a given area are identified and counted, then an estimate of the total population is made.

2. Water temperature is an important factor in determining when fish spawn.

5. Answer the following questions based on the samples you "collected."

A. Which season had these characteristics?
1. The greatest number of diatoms
2. The greatest number of blue–green algae
3. The greatest number of zooplankton
4. The warmest water
5. The most gizzard shad larvae
6. The most yellow perch larvae
7. The most sheepshead larvae

B. You have noted that the water is warmer in which sample? Water temperature is an important factor in determining when fish spawn. Which species appear to require warmer water for spawning?

C. What would be the advantage of having different fish spawn at different times?

D. You now have information about the microscopic organisms in an estuary. Using what you have learned, predict the effect of the following events on the plants and animals of the estuary:

1. Hot water is dumped into the estuary by a utility company.
2. Global warming causes the level of the creek to drop 35 cm.

Review Questions

1. Explain what is meant by population sampling.

2. Using the comparative data count of the plankton, explain how the temperature increase could affect the number of plankton in a lake. How will these changes affect other animal and fish species in the food chain?

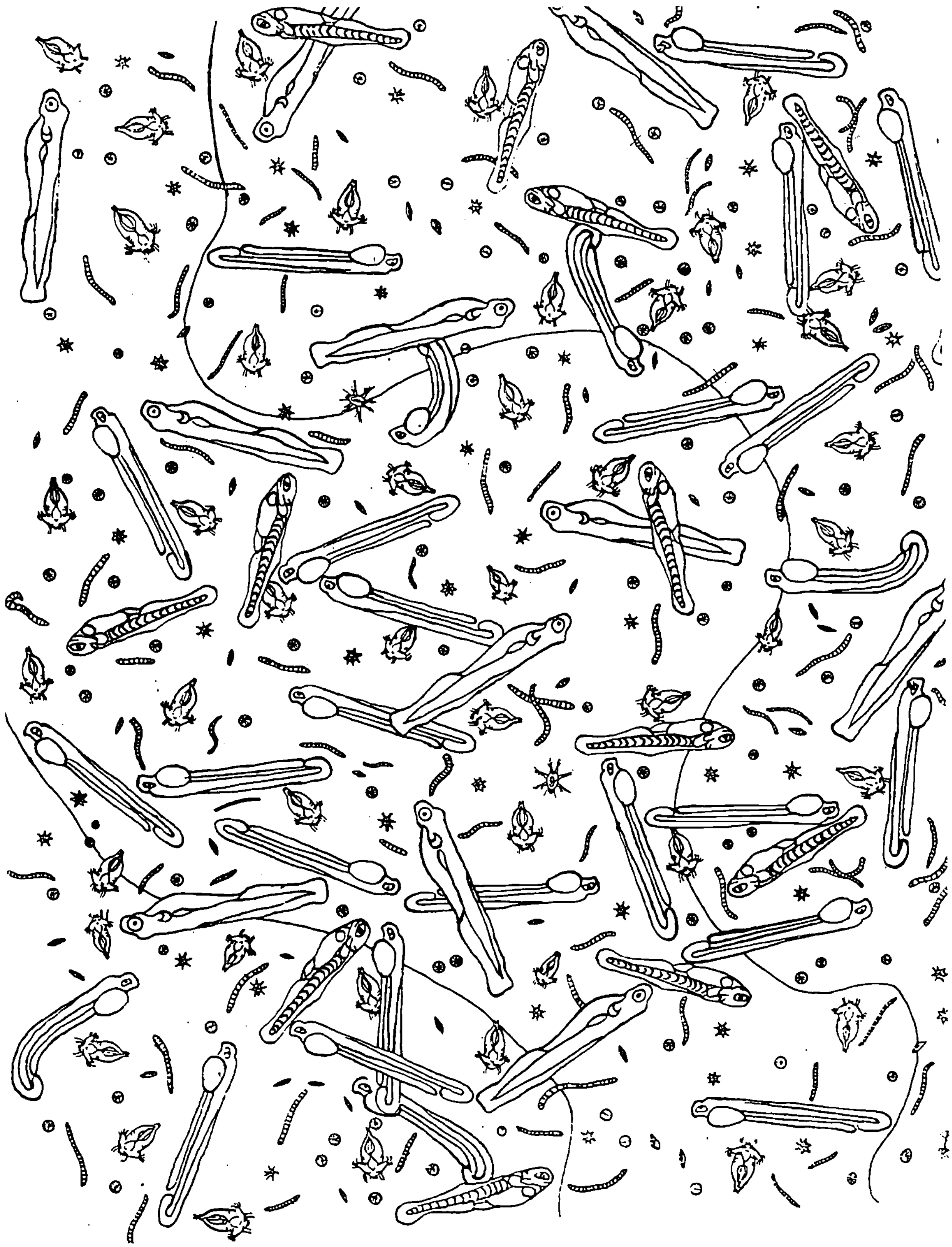


Figure 3. Estuary plankton sample, May (water temperature 13°C)

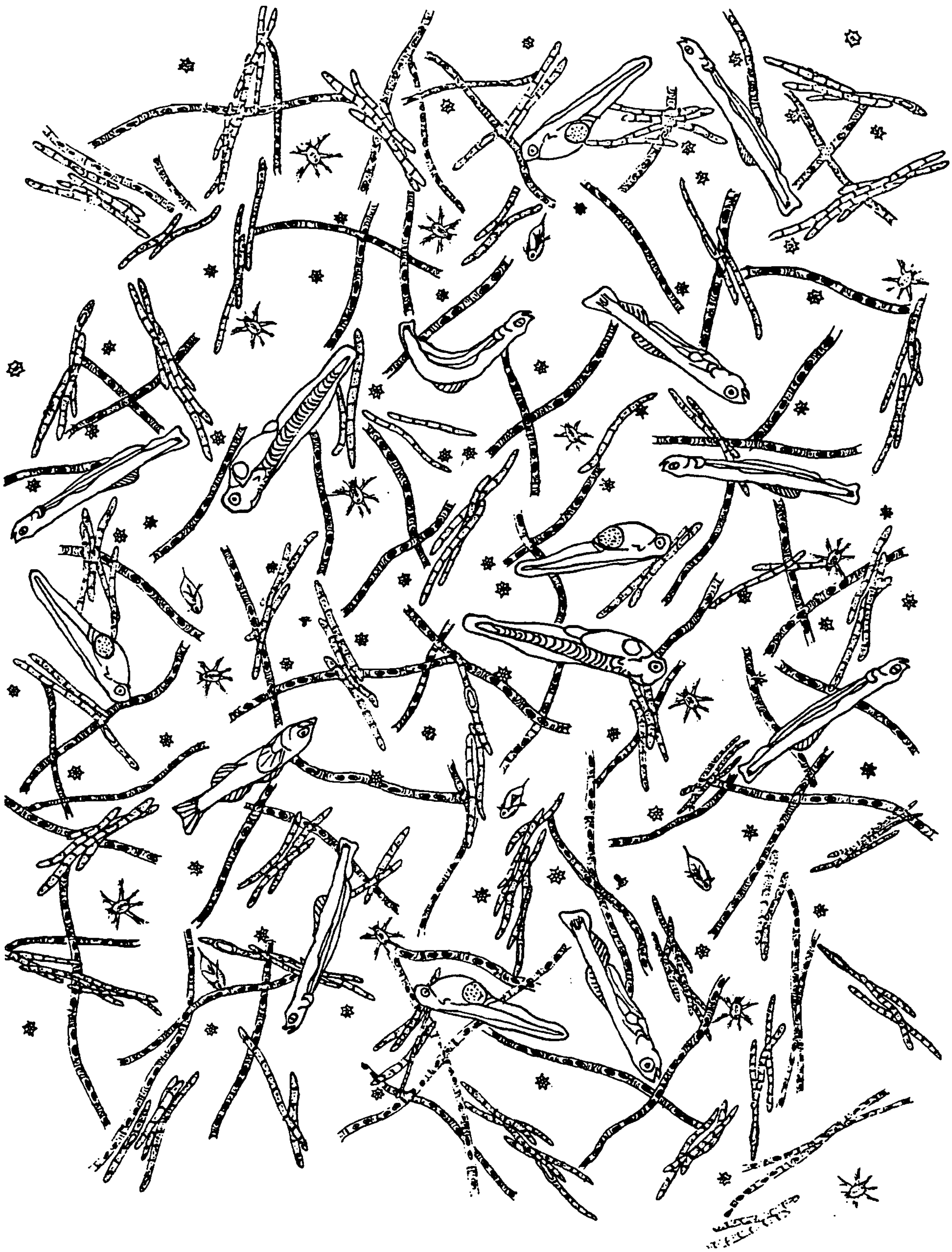
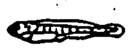
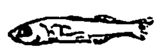


Figure 4. Estuary plankton sample, August (water temperature 21°C)

PLANKTON SAMPLE

Organism		May Sample (Fig. 6) 1	2	3	Ave.	Total Pop.	Aug. Sample (Fig. 7) 1	2	3	Ave.	Total Pop.
Algae:											
Diatoms											
Green											
Blue-green											
Zooplankton:											
Cladocerans											
Copepods											
Protozoans											
Rotifers											
Fish Larvae:											
Yellow Perch	 Yolk-sac larva										
	 Regular larva										
Gizzard Shad	 Yolk-sac larva										
	 Regular larva										
White Bass	 Yolk-sac larva										
	 Regular larva										
Sheepshead (freshwater drum)	 Yolk-sac larva										
	 Regular larva										
Emerald Shiner	 Yolk-sac larva										
	 Regular larva										

***Yolk--sac larvae have just emerged from eggs. A yolk-sac larva is younger than a regular larva.**

Figure 5. Worksheet for estuary plankton sample

Activity C: What happens to the wetlands if the shoreline migrates?

As temperatures rise, the water shoreline will fall. With that decrease in the water levels, some wetlands may not be capable of migrating with the shoreline, eliminating the important factors like species habitat, nutrient filtering, and flood protection that wetlands contribute.

Earth System Understandings

This activity focuses primarily on ESU 3 (scientific methods and technology), 4 (interactions), and 5 (change through time).

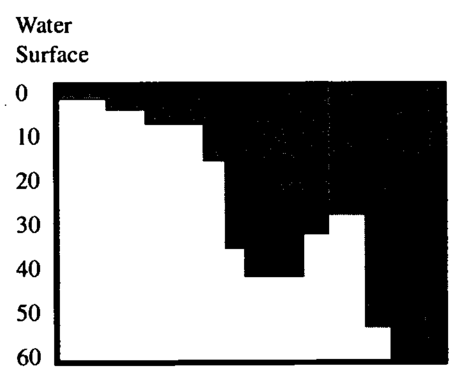
Scenario Reference

#6, What are the implications of low water levels in Great Lakes estuaries?

Notes

To create a vertical profile students should:

1. Draw a straight line across the section of the map that they want to indicate a profile. (The line should not be along a certain depth but across several depths, preferably from the shore towards the center of the lake.)
2. Draw a line on a sheet of graph paper that represents the straight line on the map.
3. Record the distance between changes in depth on the line across the map and transfer those distances to the line on the graph paper.
4. Graph the different depths (as shown below) at the appropriate distance intervals. This will create a rough picture of the steepness of the underwater slope.



Objectives

After completing this activity, students will be able to:

- Critically interpret map data.
- Discuss the mechanisms by which shorelines migrate.

Materials

- topographic map sections or other maps of nearby shoreline areas (one example given) having some wetlands
- graph paper, 2 pieces for each group
- ruler and pencil

Procedure

1. Divide the class into working groups comprised of three to four students. Ask each group to examine one or two different topographic maps and identify the wetland near the shoreline in each, using the map's key.

2. Each working group draws a vertical profile of each of the sectioned topographic maps.

3. Discuss the physical and biological factors that would influence how well a wetland would successfully follow a migrating shoreline. This would include such things as the angle of shore slope, water action (waves), types of sediments/substrates, general ability of vegetation to establish roots, speed of water dropping.

4. Discuss why a shoreline would migrate (making sure to introduce the cause of increased evaporation from climate warming).

Review Question

1. How could global warming play a role in shoreline migration?

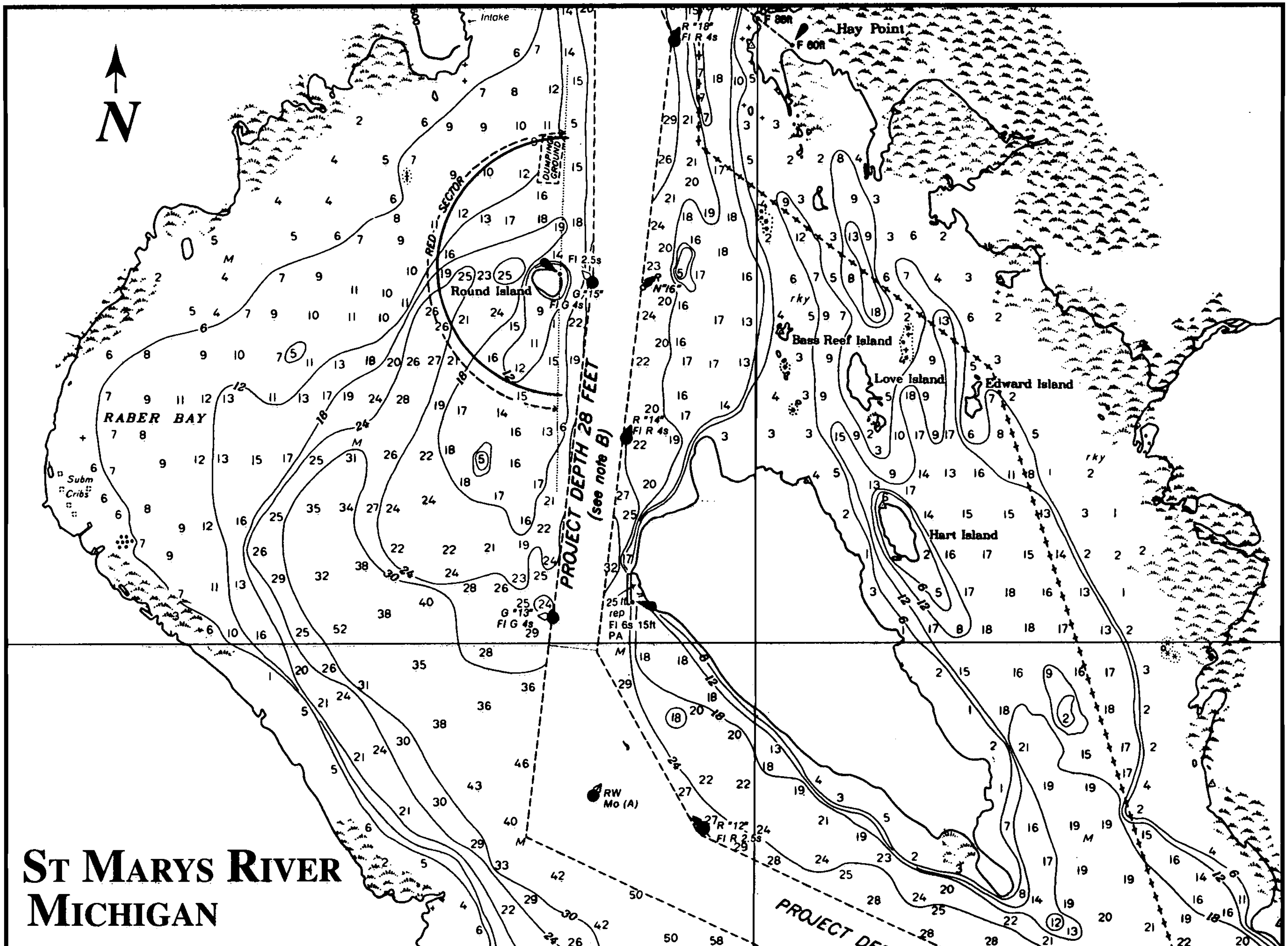
2. What shoreline characteristics must exist for a wetland to successfully migrate with a shoreline?

Extension

Ask each student to choose a plant or animal species that would be found in a wetland area. They should write a poem that expresses their knowledge and feelings about that organism. Students should also illustrate the organism as it exists in its wetland environment. Ask students to tell the class about the organism they have chosen and share the poems and drawings they have done. Small groups and poster sessions are good ways for sharing work.

Answers to Review Questions

Global warming is predicted to lower the level of the Great Lakes from 1 to 3 meters by the year 2025. For a wetland to migrate successfully, the slope of the land must be very gentle, and the change must occur slowly enough to allow sediments to accumulate.



ST MARYS RIVER
MICHIGAN
N
Hay Point
Round Island
Bass Reef Island
Love Island
Edward Island
Hart Island
RABER BAY
PROJECT DEPTH 28 FEET
(see note B)
RED SECTOR
DUMPING GROUND
Intake
Subm Cribs
RW Mo (A)

Toxic Chemicals and Global Change

A significant amount of the pollution in the Great Lakes comes from a somewhat unexpected source — the air. According to the Great Lakes Commission (1995), "The Great Lakes, large in surface area and surrounded by numerous urban and industrial centers, are particularly vulnerable to contaminants showered on them from the atmosphere. Atmospheric deposition can account for as much as 90 percent of some toxic loadings to the lakes. Scientists have long surmised that the toxic deposition problem in the Great Lakes is not merely a consequence of local emissions; persistent toxic substances released into the atmosphere thousands of miles away eventually end up in the lakes."

Efforts are now in progress to understand and curb this pollution in order to prevent its deposition into the Great Lakes. A regional *Air Toxics Emissions Inventory* is to document data on point sources and area emissions of 49 toxic air pollutants in the eight Great Lakes states. The source of information about the *Inventory* and related efforts is the Great Lakes Information Network (GLIN) on the Internet at http://www.great-lakes.net:2200/glinhome.html

Activity A. How big is the problem of airborne toxins?

When we consider the toxic chemicals that enter the Great Lakes by air, we are actually looking at three types of processes — *release* from a source (which may be natural or anthropogenic), *transport* to other locations, and *deposition* in either wet or dry forms as shown below (Figure 1).

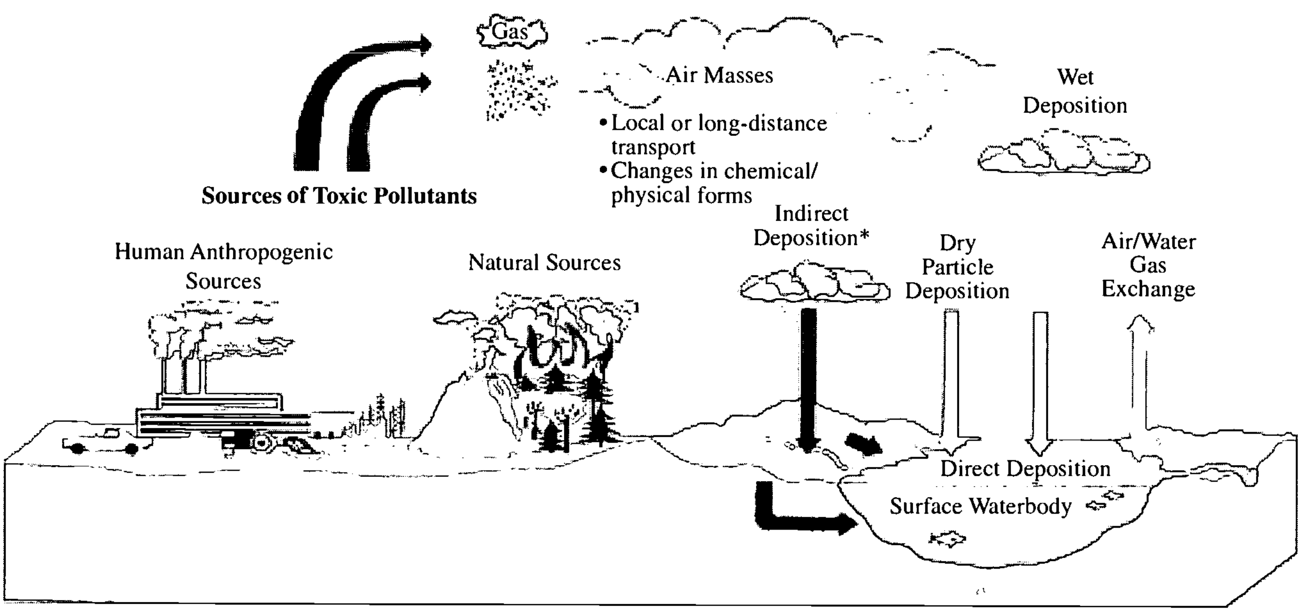


Figure 1. How does atmospheric deposition occur?
* Indirect deposition is direct deposition to land followed by runoff or seepage through groundwater to a surface waterbody. (EPA, Great Waters p.12)

The presence and impact of persistent toxic substances on all sectors of the ecosystem . . . defies boundaries and is not easily resolved through traditional technologies and regulations.

— IJC, 1992

Earth Systems Understandings

This activity focuses on ESU #2 (impact of human activity), #3 (scientific thinking and technology), and #5 (change through time). Understandings #4 and #7 are addressed in the extensions. Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#5, Will [global change] affect airborne toxins?

Materials

(per team of 4-5 students)
- copy of Charts 1-3
- graph paper
- a range of supplies for constructing a model of air pollution detection (such as a small electric fan
- 2 9x13" cake pans
- source of water, particle source such as dusty erasers or powdered drink mix
- wet deposition source such as water with food coloring in it
- contact paper, filter paper
- other items that might be useful in creating, transporting, collecting and measuring airborne pollution)

The deposition itself is considered nonpoint pollution because of its diffuse nature. However, it comes from some sources that are identifiable: *point* sources, such as factories or incinerators; *mobile* sources like cars and trucks; and *area* nonpoint sources that are the combined output of sources in a geographic area, like the dry cleaners, gas stations, and other small businesses of a community.

Of their RELEASE -> TRANSPORT -> DEPOSITION to the lakes, the release of the toxic substances is really the only process humans can control on a large scale. However, both transport and deposition could be influenced by global climate change. This activity is a series of questions to be answered with existing datasets and creative application of ideas. It invites students to explore the sources that release the toxic substances and possible methods by which the toxins can be transported and deposited.

Objectives

Upon completion of this activity, students will be able to
- describe the types and values of information available from the USEPA's Toxic Release Inventory and Great Waters Program;
- analyze the trends of toxic releases by air for the Great Lakes states;
- design a method for demonstrating and detecting the amount of airborne pollution likely to reach points at varying distances from a source;
- describe how the regional climate effects of global change could affect air pollution.

Procedure

1. **What are the sources of Great Waters "Pollutants of Concern"?**

   To answer this question, students examine Chart 1, which lists selected pollutants that are known to be deposited by air in the areas shown on the map, including coastal areas, but especially the Great Lakes, Chesapeake Bay, and Lake Champlain. All of the pollutants are toxic, they are persistent in the environment, and they have the potential to bioaccumulate through the food chain. To simplify the amount of information, teams of students could choose two pollutant types to follow through the activities, but they should also pay attention to the entire range of pollutants, sources, and effects.

Discuss with the class that some of the pollutants are no longer produced or available in the Great Lakes region, but transport by air still makes them a pollutant here.

2. **What local sources are contributors to Pollutants of Concern to the Great Waters?**

As they examine the column on "Sources of Air Emissions," students should identify local sources that fit the descriptions given. This should be discussed in light of the important contributions the sources are making to quality of life and standard of living in the community, as well as environmental impact.

Students should also consult official documents rather than simply speculating on emission sources. The EPA's Toxic Release Inventory is available online from RTK NET (the Right to Know Network) and through CD-ROMs available in local government environment offices. It can be searched by zip code to determine if air toxins are being released by the local sources suspected. Reporting such releases is a responsible thing for industry to do; it makes the polluters and the public aware of the impacts of doing business and alerts them all to the need for cleaner lifestyles. However, such groups as farmers using insecticides, as well as people driving motor vehicles producing lead, nitrogen, and POMs, do not have to report!

Notes

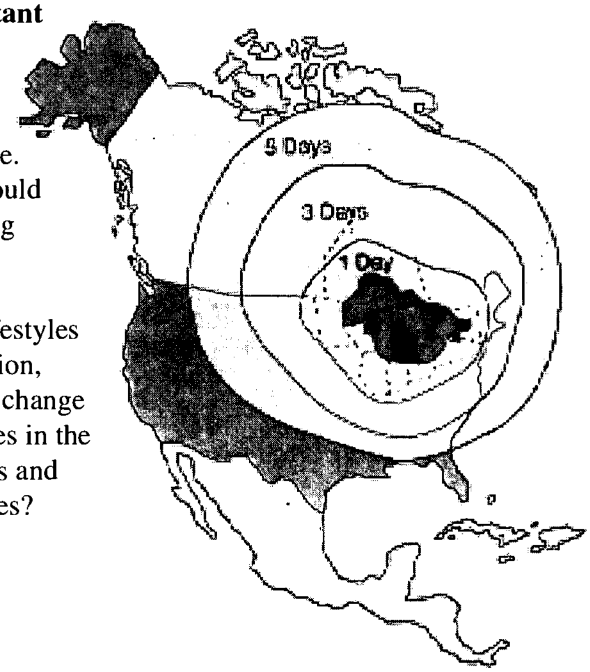
RTKnet has an Internet connection at http://rtknet.org, but complete records are available only through a long-distance modem call to 202/234-8570. Contact them by voice phone at 202/234-8494 for alternatives.

Follow this activity with those on "Responding to Global Change" in this volume.

3. **What distant sources are important contributors of pollutants?**

According to the EPA, the Great Lakes "Airshed" is a very large one. Even cleaning up local sources would not prevent air toxins from entering the Great Lakes.

a. Students should discuss how lifestyles and social conditions (cooperation, economics, etc.) would have to change in order to make desired changes in the environment. What are the costs and benefits of making these changes?



The Great Lakes "Airshed" Band indicate the approximate number of days required for airborne contaminants to be transported to the Great Lake basin. EPA, *Great Waters Index*, p.10

Chart 1. Selected Pollutants of Concern in the Great Waters and Sources of Air Emissions (EPA Great Waters 1994)

Pollutant	Examples of Use	Sources of Air Emissions
Cadmium	Used in metals production processes, batteries, and solder.	Fossil fuel and municipal waste combustion; aluminium, iron, and steel production; cadmium, copper, lead, and zinc smelting; battery manufacturing, hazardous waste, and sewage incineration; petroleum refining; lime manufacturing; soil-derived dust; volcanoes.
Chlordane	Insecticide used widely in 1970-80s. All U.S. uses except termite control canceled in 1978, use for termite control voluntarily suspended in 1988. Use of existing stocks permitted.	Insecticide application, volatilization from soils, water, and treated building foundations due to past insecticide application; suspension of eroded soil particles.
DDT / DDE	Insecticide used widely after introduction in late 1946 until significantly restricted in U.S. in 1972. Still used in other countries. Used in U.S. for agriculture and public health purposes only with special permits.	Insecticide application, volatilization from soils and water due to past insecticide application.
Dieldrin	Insecticide used widely after introduction in late 1940s. Used in U.S. for termite control from 1972 until registration voluntary suspended in 1987.	Insecticide application, volatilization from soils and water due to past insecticide application.
Lindane	Main component of lindane, an insecticide used on food crops and forests, and to control lice and scabies in livestock and humans. Currently used primarily in China, India, and Mexico. U.S. production stopped in 1977; however, many uses are still registered, but are expected to be voluntarily canceled in the future.	Insecticide application, volatilization from soils and water due to past insecticide application.
Lead and Compounds	Used in gasoline and paint additives, storage batteries, solder, and ammunition. Released from many combustion and manufacturing processes and from motor vehicles. Use in paint additives restricted in U.S. in 1971. U.S. restrictions on use in gasoline additives began in 1973 and have continued through the present, with a major use reduction in the mid-1980s.	Fossil fuel combustion; aluminium, iron, and steel production; lead smelting; ferroalloys production; battery manufacturing; hazardous waste and sewage sludge incineration; municipal waste combustion; petroleum refining, lime manufacturing; cement manufacturing; chlorine and caustic soda manufacturing; pulp and paper production; combustion of waste oil; paint application; motor vehicles; forest fires; eroded soil particles; volcanoes.
Mercury and Compounds	Used in thermometers, electrical equipment (such as batteries and switching equipment), and industrial control instruments. Released from many combustion, manufacturing, and natural processes. Banned as paint additive in U.S., for interior paint (1990) and for exterior paint (1991).	Fossil fuel combustion, copper and lead smelting; hazardous waste, municipal waste, medical waste, and sewage sludge incineration; lime manufacturing; cement manufacturing; chlorine and caustic soda manufacturing; paint application; suspension of eroded soil particles, evasion from soils and water; volcanoes.
Polychlorinated biphenyls (PCB)	Industrial chemicals used as coolants and lubricants and in electrical equipment (transformers and capacitors). In the U.S., manufacture stopped in 1977, and uses were significantly restricted in 1979. Still used for some purposes because of stability and heat resistance, and still present in certain electrical equipment used throughout U.S.	Incineration and improper disposal of PCB-contaminated waste; disposal of waste oil; malfunction of PCB-containing transformers and capacitors; electrical equipment manufacturing; pulp and paper production; volatilization from soils and water; municipal solid waste incineration and unregulated combustion.
Polycyclic organic matter (POM)	Naturally occurring substances that are byproducts of the incomplete combustion of fossil fuels and plant and animal biomass (e.g., forest fires). Also, byproducts from steel and coke production and waste incineration.	Combustion of plant and animal biomass, fossil fuels and municipal waste; petroleum refining; steel and aluminium production; coke production and byproduct recovery; creosote production and wood preserving; surface coating of autos and light duty trucks; asphalt processing; dry cleaning (petroleum solvent); forest fires.
2,3,7,8-Tetra chlorodi benzo-p-dioxin (TCDD)	Byproduct of combustion or organic material containing chlorine and of chlorine bleaching in pulp and paper manufacturing. Also a contaminant in some pesticides.	Hazardous, including sewage sludge incineration; municipal waste combustion; combustion of fossil fuels and organic materials containing chlorine; byproduct of various metals recovery processes, copper smelting; accidental fires of treated wood products and PCB-containing transformers and capacitors; improper disposal of certain chlorinated wastes; pesticide production, application, and spills; pulp and paper production; volatilization from, and erosion of, dust from landfill sites; forest fires.
Toxaphene	Insecticide used widely on cotton in the southern U.S. until the late 1970s. Most U.S. uses banned in 1982; remaining uses canceled in 1987.	Insecticide application; volatilization from soils and water due to past insecticide application.

Chart 2. Toxic Releases by air in Great Lakes states, 1990-93. (-RTK NET)

Year	State	TRI pounds from stack air	TRI pounds from fugitive air	Total air toxins
1990	IL	57391103	33145881	90536984
1991	IL	55129856	28337929	83467785
1992	IL	50520449	23418974	73939423
1993	IL	43967230	19043824	63011054
Total	IL	207008638	103946608	310955246
1990	IN	67652416	41595852	109248268
1991	IN	59580387	33550843	93131230
1992	IN	58382077	26660384	85042461
1993	IN	53339189	23536681	76875870
Total	IN	238954069	125343760	364297829
1990	MI	61885749	22287721	84173470
1991	MI	53585439	18770944	72356383
1992	MI	50908819	16622228	67531047
1993	MI	51134898	16726566	67861464
Total	MI	217514905	74407459	291922364
1990	MN	42927365	7965081	50892446
1991	MN	32072713	7462350	39535063
1992	MN	23962351	5800445	29762796
1993	MN	17037541	5301484	22339025
Total	MN	115999970	26529360	142529330
1990	NY	51509864	23994992	75504856
1991	NY	43808425	17563959	61372384
1992	NY	39044653	16456900	55501553
1993	NY	30929618	13925366	44854984
Total	NY	165292560	71941217	237233777
1990	OH	82964283	37305207	120269490
1991	OH	72698854	33937499	106636395
1992	OH	65059157	28732506	93791663
1993	OH	57654861	26942846	84597707
Total	OH	278377155	126918058	405295213
1990	PA	43977773	34132223	78109996
1991	PA	39778738	28543068	68321806
1992	PA	37502293	25724047	63226340
1993	PA	32019747	20051830	52071577
Total	PA	153278551	108451168	261729719
1990	WI	33504530	10821515	44326045
1991	WI	29188553	8359246	37547799
1992	WI	29399800	7692449	37092249
1993	WI	26043982	7203245	33247227
Total	WI	118136865	34076455	152213320

The Toxic Release Inventory (TRI) is an inventory of the types of quantities of toxic chemicals released by manufacturing facilities. Data are collected from reports to the EPA.

Stack air emissions occur through confined air streams such as stacks, vents, ducts, or pipes. Fugitive air emissions are not released through a confined stream. They include equipment leaks, evaporative losses, and ventilation releases.

b. Trends show decreasing amounts of toxic releases by air. Total amounts differ greatly by state.

c. Answers will vary and can be checked on RTK NET or through atlases.

b. Look at Chart 2, with its pounds of toxic releases by air by state. Assign teams to analyze the data for different states, graphing the trends in air pollution emissions, and then comparing the total amounts across states.

c. Compare the population of the assigned state, and other demographic and economic indicators, with the amount of toxic releases reported. Do the amounts of release seem to be related to particular factors within the states?

4. In general, more intense and frequent storms are expected, but with less precipitation overall, resulting in lower lake volume. While patterns of air movement may not change noticeably, the air toxin transport may be a more serious problem, and the toxins will deposit in less water, resulting in a greater concentration of pollution.

4. **How will Great Lakes global change climate patterns affect airborne toxins?**

Students should reread the Scenario #5 reports on changing climate and describe what is likely to happen to

a. frequency of storms
b. intensity of storms
c. extremes of weather
d. patterns of air movement
e. amount and distribution of precipitation
f. volume of lakes

5. **What are the potential human health and wildlife effects associated with Pollutants of Concern?**

a. Teams examine the data in Chart 3a and 3b. Remember that the effects listed are for the total pollutant present, not just the air-carried component.

Chart 3a illustrates the variety of health effects observed in wildlife in the Great Lakes Basin. Blank cells do not necessarily mean there is no effect on wildlife, only that research has not been performed on the species.
(modified from Hilleman, 1993. *Chemical and Engineering News.*)

Note: *Effects listed have been in scientific literature published during the past decade*

Species	Reproductive effects	Eggshell thinning	Generational effects	Deformities	Organ damage	Behavioral changes	Hormonal changes	Metabolic changes 'wasting'	Immune suppression	Tumors
Bald eagle	●	●	●	●		●		●		
Beluga whale	●			●	●		●		●	●
Black-crowned night heron	●	●		●						
Brown bullhead			●	●			●		●	●
Caspian tern	●		●	●		●		●		
Chinook-coho salmon	●				●		●			●
Common tern	●				●	●		●	●	
Double-crested cormorant	●	●	●	●	●	●		●		
Forster's tern	●		●	●	●	●		●		
Herring gull	●	●	●	●	●	●	●	●	●	
Lake trout	●		●		●	●		●		
Mink	●		●		●			●		
Osprey	●	●								
Ring-billed gull	●			●				●	●	
Snapping turtle	●	●	●	●	●			●		
White sucker	●		●				●		●	●

Chart 3b. Potential human health effects associated with Pollutants of Concern

Potential Effects on Human Health

Pollutant	Cancer	Reproductive/ Restrictions	Neurological Behavioral	Immunological	Endocrine	Other Noncancer
Cadmium and compounds	Probable	●	●	●		Respiratory and kidney toxicity
Chlordane	Probable	●	●	●	●	Liver toxicity
DDT/DDE	Probable	●	●	●	●	Liver toxicity
Deildrin	Probable	●	●	●		Liver toxicity
Lindane	Probable	● (gamma-HCH)	●	●		Kidney and liver toxicity
Lead and compounds	Probable	●	●	●	●	Kidney toxicity
Mercury and compounds		●	●	●		Kidney toxicity
PCBs	Probable	●	●	●	●	Liver toxicity
Polycyclic organic matter	Probable	●		●		Blood cell toxicity
2,3,7,8-TCDD	Probable	●	●	●	●	Integument toxicity
Toxaphene	Probable	●	●	●	●	Cardiovascular effects; liver toxicity

b. Given the contributions of the pollution sources to quality of life and/or standard of living, is there enough evidence here to demand that the sources be eliminated?

5b. Discussion should focus on costs and benefits of the sources.

6. **To what extent does air transport contribute to overall pollution in the Great Lakes?**

An example of the approximate amount of PCBs in Lake Superior from various sources is shown in Figure 2. Bold figures tell how much of the pollutant is in different locations (atmosphere, water, sediment).

a. Does it appear that the atmosphere is contributing the greatest amount of the PCBs directly?

b. Not all lakes are as subject to contamination by air (Figure 3). Examine the implications of the percentages in this figure. How important are the following in determining the percentage of pollutants entering by air transport?
- the upstream lake
- the surface area of the lake
- geographic proximity to pollutant sources

6a. Most are entering the water from "recycling," or re-suspension of formerly settled or buried material. Of the direct sources of input, however, the atmosphere component is greater than that of the river inflow. Case studies such as this demonstrate that atmospheric deposition may be an important contributor of toxic chemicals.

6b. All are extremely important influences.

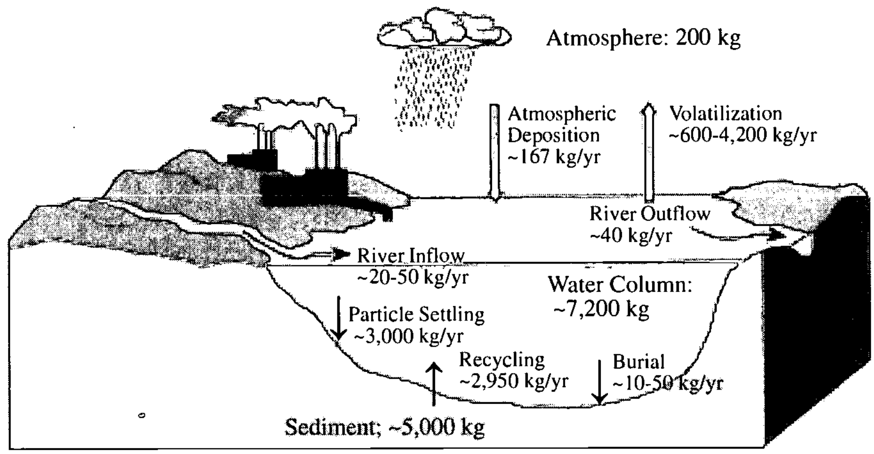


Figure 2. Mass balance of PCBs in Lake Superior
Numbers represented are approximations. (EPA, Great Waters p.49)

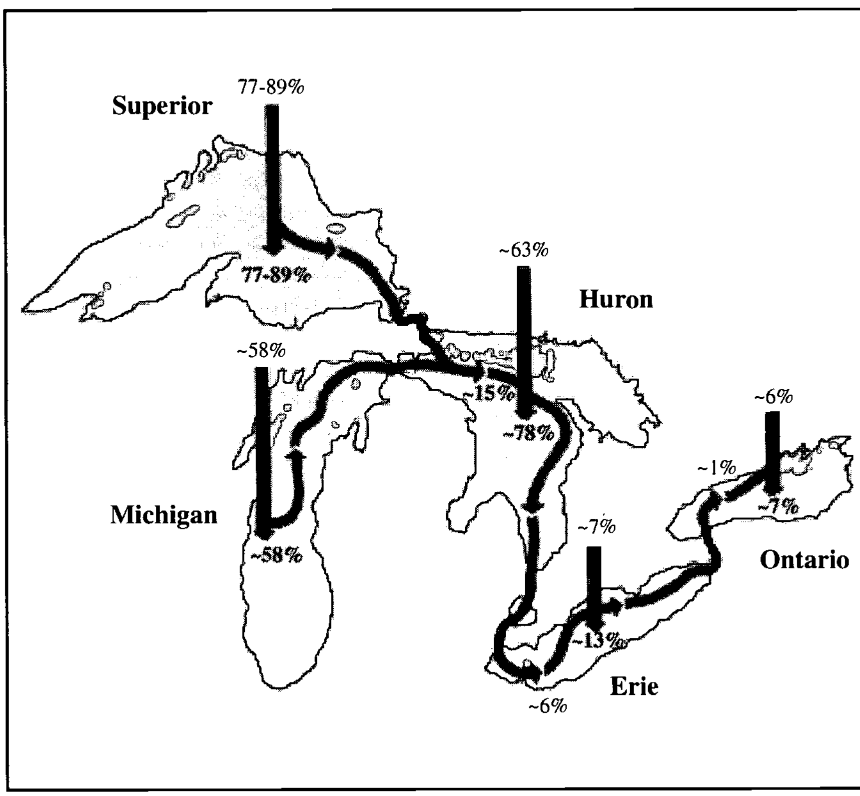


Figure 3. Atmospheric loading of PBCs to the Great Lakes
Arrows and flow depict pollution that deposits from the atmosphere directly to water surfaces and travels through the Great Lakes system. The percentages reflect the amount of such pollution compared to that from all other routes. For example, approximately 63 percent of Lake Huron's PCB loading is from atmospheric deposition to the lake itself and approximately 15 percent is from atmospheric loading to the upstream lakes. The remainder of Huron's PCB loading is from nonatmospheric sources (approximately 22 percent). (EPA, Great Waters, p.54)

7. **How can we demonstrate and document long-range pollution transport?**

Within teams, students design a method of testing how far various pollutants can travel by air from a point source. Make available a spray bottle with food coloring in water as a source of wet deposition, or some erasers full of chalk dust, or a blower bottle with powdered drink mix to puff out for dry deposition. The following design rules apply:

a. Pollutants must be released in a way that carries them AWAY from other students. The pollutant release will be in two or three episodes only (3 squirts, eraser pats, etc.).
b. Pollutants are released in front of a small fan or hair blower mounted for a steady flow of wind.
c. Deposition should be tracked by distance from the source, with some measures near the source, others farther away in a meaningful pattern.
d. It should be possible to demonstrate to others that deposition has occurred in the amounts and places reported. (Evidence should be provided.)
e. While the question here is pollution over water, it is understood that pollution over any surface constitutes acceptable evidence. (The measure may be how much pollution gets in the water, or how much gets on a paper, etc.)

A sample design might be as follows: Set up three pans with equal amounts of water, at regular distance intervals away from the fan. Pat erasers together three times in front of the blowing fan, and watch which of the pans of water gets dust on top. Filter off the dust to measure how far the pollution traveled and which lake got the most pollution by weight or volume. If powdered drink mix is used, a colorimetric comparison of the waters could be the measure.

Review Questions

1. Suppose you are a citizen who suspects that a local industry is releasing harmful gases, even though there is no bad odor in the air. What information sources would you consult to find out the types and amounts of emissions the company releases by air? What kinds of information must be reported by those who release toxic emissions? What other pollution sources might be responsible for your local air quality but are exempt from reporting?

Answers to Review Question

1. The EPA has prepared a number of documents to assist citizens using the TRI and other EPCRA (Emergency Planning and Community Right-to-Know Act) data. To request TRI reports and other documents, citizens should call their State Section 313 contact or the toll-free EPCRA Information Hotline at 1-800/535-0202.

Only manufacturing facilities that have 10 or more full-time employees and meet the established thresholds for manufacturing, processing, or otherwise using listed chemicals must report their releases and transfers. Thresholds for manufacturing are currently 25,000 pounds for each listed chemical. Facilities are required to provide release and transfer estimates for each environmental medium and type of transfer, locations of off-site transfers, and waste treatment methods and efficiencies.

There are some limitations of the TRI data. 23,000 facilities submit over 82,000 reports each year yet this captures only a portion of all toxic chemical releases nationwide. Non-manufacturing facilities currently are not required to report (such as mining and electric utilities) and are oftentimes sources of significant releases of toxic chemicals. Many facilities that are required to report either do not file at all, or do not file all of the necessary reports. A company may also use its own estimation techniques if actual measurements are not available and these techniques are not monitored for accuracy. Although additional information is necessary to assess exposure and risk, TRI data can be used to identify areas of potential concern.

2. The older people you know claim that even five years ago the air was not as polluted as it is now. React to this statement on the basis of information available to the public.

3. As an environmental scientist you are hired by a polluting industry to prove to the government environmental agency that even though some toxic chemicals are being released to the air, they are not being deposited to the lakes. Describe how you would monitor the transport and deposition of airborne emissions from the company to check the amount reaching both nearby and distant waters.

Extensions

1. Develop a concept map showing how gasoline contributes to toxic air pollution and global warming but also to quality of life in North America.

2. Make a list of the careers or college majors that would be needed among the people who produce, contribute to, and use the Toxic Release Inventory. What additional careers would be involved with pollution prevention using the information in the Inventory?

References

"Toxic air emissions in the Great Lakes region." Special Insert. *Great Lakes Commission Advisor* (Newsletter of the Great Lakes Commission) 8(3):1-2A. May/June 1995.

USEPA, 1994. Two free documents served as information sources for this activity:

Deposition of air pollutants to the great waters. First report to Congress. EPA-453/R-93-055. and
The EPA Great Waters Program: An introduction to the issues and ecosystems. EPA-453/B-94-030.

Limited free copies are available from the producers of the reports: Office of Air Quality Planning and Standards, Pollutant Assessment Branch (MD-13),USEPA, Research Triangle Park, NC 27711. Attention: Great Waters Documents.

Activity B: Where do all the toxins go? (Internal View)

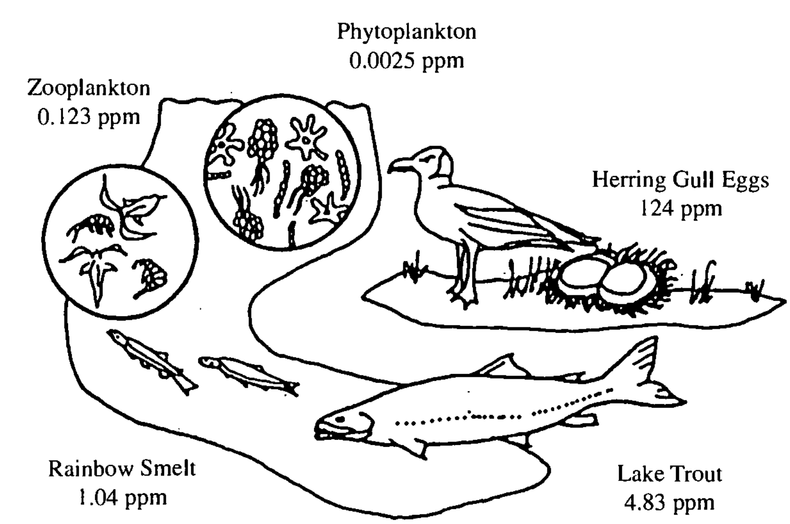
An unfortunate byproduct of the high standard of living enjoyed by developed nations is a heavy reliance on chemicals. Chemicals are used in agriculture and industry and are unintentional byproducts of many human activities. Many of the chemicals that we have become so dependent on are entering our Great Lakes as toxic fallout from the air.

In what ways do chemicals present a problem in the Great Lakes ecosystem? Not very often do we hear about massive kills from chemicals. The effects are much more subtle. Many chemicals enter the food chain at the lower end and accumulate and magnify within organisms throughout the chain. Those carnivores at the top of the food chain, including humans, have the highest levels of these toxins in their bodies. One of the foods that is popular with humans is fish — fatty fish such as trout and salmon accumulate the most toxins through the food chain, and larger fish are the most dangerous. People are warned not to eat fish that exceed a certain length (such as brown trout over 18 inches in Lake Ontario) and to restrict consumption of smaller fish of these species.

The characteristics of a chemical that determine whether or not it will be an environmental hazard are: its toxicity, its persistence, and its affinity for water. Chemicals that have no affinity for water tend to have an affinity for lipids (fats). They combine with the fatty substances in an organism's body, and if persistent, will remain with the organism until it dies or is consumed.

PCBs (polychlorinated biphenyls) are a class of toxic chemicals that appear in many Great Lakes fish. They were frequently used as a coolant, especially around electric transformers, because they conduct heat but not electricity. All production of PCBs was stopped in 1976 after it was discovered how toxic they were. However, they do not break down in nature, and many products containing them are still around. As old transformers and other such equipment are discarded, PCBs may leak into the air or water. PCBs then enter the marine food chain and collect in the fatty tissues of fish. PCBs cause carnivores such as cormorants, and scavengers such as gulls, to develop reproductive problems or deformities.

BIOMAGNIFICATION OF PCBs



Environment Canada and U.S. Environmental Protection Agency (1987)

In this activity, iodine is used as an example of a fat soluble compound. The iodine atoms associate themselves with oil (fat) molecules and cause a color change. In the lake environment, chemicals such as DDT and PCBs are fat soluble. They tend to be extracted from the lake water and concentrated in fatty substances in plants and animals. High concentrations of these chemicals are found in the belly fat and under the skin of fatty fish such as lake trout, salmon, and chub.

Materials

- iodine crystals (8 per demonstration)
- screw-top vial (about 75 ml)
- 20 ml water
- 20 ml. vegetable oil
- Ohio Sea Grant Fact Sheet 007: *PCBs: Their history and our health*. (optional)
- chart of fish advisories (optional)

Answers

a. The sugar dissolves.
b. The butter would not dissolve; it would stay in lumps.
c. Solubility refers to the ability of one substance to become evenly distributed in another substance.
d. Some of the iodine dissolves — some does not. The water turns light brown.
e. The iodine was extracted into the oil because the iodine is more soluble in fat than in water. Since there is no more iodine in the water, the water clears up. The oil layer turns pink, indicating the presence of iodine.
f. Oil
g. The oil represents fat; water represents other bodily fluids such as blood, saliva, sweat.
h. PCBs accumulate in the fat.
i. They can't be washed out because the fats won't dissolve in these fluids.
j. To prepare fish safely, clean all the fat off before cooking, and broil the fish on a rack so that it doesn't cook in its own juices. Note that this method would not remove poison metals such as mercury, because they accumulate in muscle tissue.

Note

This activity was originated by Michigan Sea Grant in its curriculum activity, "A fish fat phenomenon" (Great Lakes Fishing in Transition)

OBJECTIVES

When students have completed this activity, they will be able to demonstrate how chemicals accumulate in fish fat, the biopathways of the toxins in the fish's body, and ways to prepare fish to avoid consuming the toxins.

PROCEDURE

1. Introduce the concept of solubility to the students. Ask the following questions:
   a. What happens to a teaspoon of sugar when you put it into a glass of water?
   b. What would happen to a pat of butter if you mixed it into a glass of water?
   c. What is meant by *solubility* ?

2. As a demonstration, put the iodine crystals in the vial with 20 ml of water. Tighten the lid and allow the students to pass the vial around and shake it.
   d. What happened to the iodine when it was mixed with the water?

3. Open the vial and pour in 20 ml of vegetable oil. Replace the lid and pass the vial around for more shaking.
   e. What happened when the oil is added? Why?
   f. In which substance is iodine more soluble, water or oil?
   g. What type of bodily substance in an animal does the oil represent? The water?
   h. Where do PCBs accumulate in fish and other animals?
   i. Why can't the PCBs be "washed out" by blood or urine?
   j. If you want to consume fish, but are not sure if it contains PCBs, how would you prepare it to be safe?

4. Distribute the fact sheet on preparing your catch (#007). If possible, have a student who is an experienced angler demonstrate proper fish cleaning. Other students should note where fat is found in the fish's body.

5. Gravid fish (full of eggs) carry most of their toxin load in the eggs. Discuss the implications of this for
   a. using fish eggs as bait,
   b. fish that feed on fish eggs, and
   c. the safest time to catch female fish.

6. The use of chemicals has become part of the lifestyle of people living near the Great Lakes.
   d. If all the toxic chemicals were eliminated from the environment, would everyone be pleased? Which professions would suffer without the chemicals? Which professions are impacted now by the presence of toxic chemicals?

EXTENSIONS

1. Investigate the existing and proposed cooperative regulations between the United States and Canada regarding protection of the Great Lakes environment. Do you feel that they are sufficient, or can they be strengthened?

2. Suppose a state or province decided to regulate commercial fishing so that consumers would receive fish with less chance of contamination. Use Ohio Sea Grant's *PCBs in Fish: A Problem?* to role play the issues that would have to be addressed to strengthen environmental regulations.

Answers

a. Fish eggs used as bait do not have time to be digested. Therefore, they would be relatively harmless to the fish and the angler.
b. Fish that eat fish eggs regularly are exposed to a large amount of toxins. The more they eat, the more they bioaccumulate.
c. The safest time to catch female fish would be when they have just spawned and rid themselves of the toxic load. However, fish flesh sometimes becomes less desirable for food at such a time (it may be softer and have a darker color). If the fish were caught before spawning, while still gravid, the problem might be eliminated. People do not usually eat fish eggs (except for caviar). Fishing at this time could seriously reduce the next year's population of fish.
d. Accept student brainstormed answers and discuss them. Americans depend on toxic chemicals for a variety of things; for instance, the fuel we use to power our vehicles (gasoline) is toxic. Toxic chemicals are components of most paints, plastics, batteries, roofing materials and pesticides used in farming. They are also used in developing film, dry cleaning, producing paper, making many medical supplies (X-ray film), purifying water for public use, caring for lawns, and a large variety of other things.

Teacher's Note

A 1995 public health advisory chart that indicates the fish that are considered dangerous to eat is located in the following activity. Local information is available wherever fishing licenses are sold.

Activity C: Where do all the toxins go? (External View)

Bioaccumulation is the build-up of chemicals in an organism's body — the longer an organism lives, the more it absorbs. When an older, large lake trout is caught, the concentration of toxins in its body could be a million times that of the original concentrations in the water. *Biomagnification* results when toxins become increasingly concentrated as they pass through the food chain. When a fish feeds on zooplankton, for example, the fish takes up toxins in all of the plankton it eats. In the fish, many of the toxins accumulate in its fatty tissues. When a gull or an eagle feeds on the fish, the bird takes up all of the toxins the fish has accumulated from all the contaminated organisms it has ever eaten. Therefore, the higher up an organism is in the food chain, the greater the amount of toxins it is likely to consume.

Materials

Each group will need:
- copy of Table 1
- copy of *human activities and industry* cards
- 1 *toxin* card
- copy of *food chain cards*
- copy of *effects of toxin* cards
- copy of *plants and phytoplankton* cards
- scissors
- posterboard or butcher paper
- glue

Objectives

When students have completed this activity, they will be able to describe how bioaccumulation and biomagnification of toxins in the food chain cause health disorders in humans and animals.

Procedure

1. In advance, prepare cards for the teams. Each of the eight themes (e.g., fish, mammals, etc.) should be on a different color paper.
2. Students should work in groups of three to four people. Each group should be given a toxin (one of the toxin cards), and all of the other cards in order to trace the toxin from its origin to its effects in animals and humans and/or animals. Table 1 will provide source and effect information on the toxins.

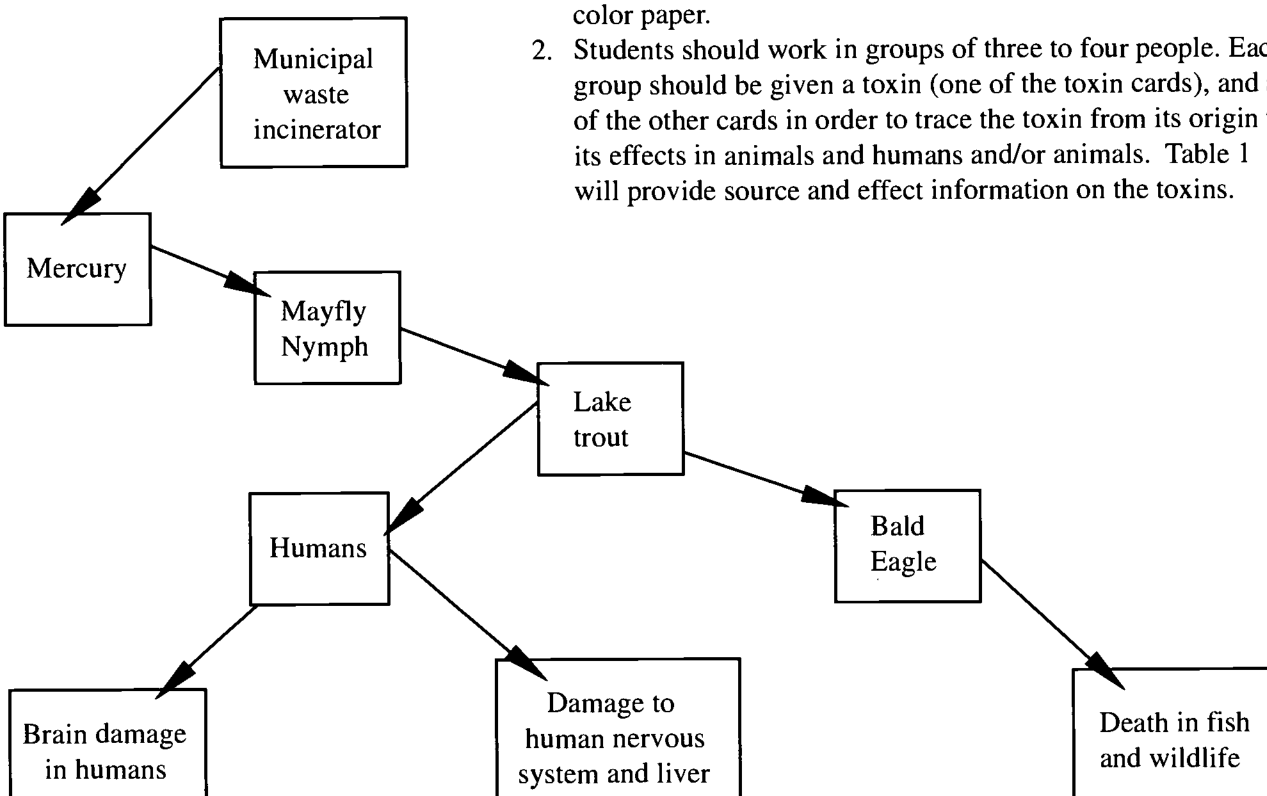


Table I. Toxins Source and Effect Information

Name of Toxin	Uses	Source of Toxin	Effects of Toxin
Lead	Used in gasoline, paints, glazes, pipes, and roofing materials	Burning leaded fuels, incinerator emissions, boilers	Toxic effects on humans, fish and wildlife; can cause brain damage
Arsenic	Used in pesticides, smelters, glass production	Pesticide use, coal combustion, primary copper smelters	Poisonous to humans, fish and wildlife
Mercury	Used in batteries, paints, industrial instruments, and pulp and paper mills	Natural, coal combustion, municipal waste incineration, copper smelting, sewage incineration	Affects the nervous system and permanent damage can result; the brain may also be damaged
Benzopyrene (BaP)	Not used alone but is found as a by-product of burning fossil fuels	Combustion processes, such as wood burning, cigarette smoke, and coke oven emissions	Believed to be cause of high incidence of tumors in fish; carcinogen
Hexachlorobenzene	Used to control insects	Pesticide use, manufacture of chlorinated solvents	Linked to nerve and liver damage; suspected to cause birth defects
Additional Airborne Toxins No Longer Produced in the USA:			
PCBs	Once used in industrial products-paints, plastics, electrical transformers	Existing landfills, spills, leaking transformers	Illness develops in humans; fatally toxic to fish and wildlife
DDT, dieldrin	To control insects, fungus, rodents, and weeds	Banned in USA, but still used in Mexico, Central and South America	Will accumulate in humans, fish and wildlife; can cause cancer in humans; toxic to fish and wildlife
Toxaphene	Pesticide used on cotton crops	Was used in southern states, including Texas, Georgia, Alabama and Louisiana	Extremely toxic to fish
Dioxin	Not used alone but is found as a by-product of manufacturing herbicides	Improper incineration of herbicides and leaching from land disposal	Human illness, livestock mortality, extremely toxic

Sources: *Hilleman, 1988; EPA, 1987*

Review Questions

1. With the use of the constructed food chain, explain what bioaccumulation and magnification are and how these factors cause health disorders in humans and animals.
2. List and explain different types of human activities that produce airborne toxins and what effects these toxins have on humans and animals.

Extensions

1. Look up information on the percentages of toxins found in the Great Lakes that probably reached there on air currents. Use your maps to determine where these toxins may be originating.
2. Do a study on how incinerators work and how they are regulated.
3. Choose a city and discuss the human health effects that might be found in its residents as a result of the airborne pollutants.

Answers to Review Questions

1. Varies by choice of toxin.
2. Refer to Chart 1 in Activity A of this section and Table 1 of Activity C, which is on this page.

Teacher's Note

The following page contains a public health advisory chart, which indicates the fish that are considered dangerous to eat. These restrictions are a reflection of the bioaccumulation of toxins in those fish.

Public health advisories for Great Lakes fish

	Restrict Consumption*	Do not eat
Lake Michigan	Lake trout 20" to 23" Coho salmon over 26" Chinook salmon 21 to 32" and Brown trout up to 23" [B] Walleye over 22" [C]	Lake trout over 23" Chinook salmon over 32" Brown trout over 23" Carp Catfish Whitefish over 23"
Lake Superior	Lake trout between 20 and 30" Walleye up to 26" [B]	Lake trout over 30" Walleye over 26" Ciscowet
Lake Huron	Lake trout Rainbow trout Brown trout up to 21" [B]	Brown trout over 21"
Lake Erie	Walleye Freshwater Drum Carp under 20" Coho salmon White perch Steelhead trout Smallmouth bass White Bass [A] and [B]	Catfish Carp over 20" Lake trout
Lake Ontario	White perch Coho salmon up to 18" Rainbow trout up to 18"	American eel Channel catfish Lake trout Chinok salmon Coho salmon over 21" Rainbow trout over 25" Brown trout over 18"

** Restricted consumption: No more than one meal per week, or*
[A] Do not eat more than one meal a month of these fish
[B] Nursing mothers, pregnant women, those who anticipate bearing children, and children under age 16 should not eat these fish.
[C] The above-mentioned group should not eat more than one meal a month of these fish.
For the most up-to-date information, contact the Michigan Department of Public Health Risk Assessment, at 1-800-648-6942.

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Toxins	**DDT**	**PCBs**
Toxins	**Dioxins**	**Toxaphene**
Toxins	**Mercury**	**Lead**
Toxins	**Arsenic**	**Benzopyrene**
Toxins	**Hexachloro-benzene**	**Dieldrin**
Effects of Toxins	**Human Cancers**	**Brain Damage in Humans**

Effects of Toxins	**Tumors in Fish**	**Birth Defects in Humans**
Effects of Toxins	**Death in Fish and Wildlife**	**Damage to Human Nervous System & Liver**
Effects of Toxins	**Human Illness**	**Livestock Mortality**
Plants & Phytoplankton	**Cattails**	**Blue-Green Algae**
Plants & Phytoplankton	**Water Lilies**	**Duckweed**
Plants & Phytoplankton	**Rice Cutgrass**	**Purple Loosestrife**

Food Chain: Birds	**Mallard Duck**	**Bald Eagle**
Food Chain: Birds	**Seagull**	**Blue Heron**
Food Chain: Birds	**Red-Tailed Hawk**	**Blue-Winged Teal Duck**
Food Chain: Fish	**Lake Trout**	**Yellow Perch**
Food Chain: Fish	**Coho Salmon**	**Walleye**
Food Chain: Fish	**Catfish**	**Alewives**

Food Chain: Mollusks, Insect Larvae and Zooplankton	**Caddisfly**	**Snails**
Food Chain: Mollusks, Insect Larvae and Zooplankton	**Zebra Mussels**	**Daphnia (Zooplankton)**
Food Chain: Mollusks, Insect Larvae and Zooplankton	**Mayfly Nymph**	**Freshwater Clams**
Food Chain: Mammals	**Mice**	**Beaver**
Food Chain: Mammals	**Red Fox**	**Raccoon**
Food Chain: Mammals	**Rabbit**	**Muskrat**

Food Chain: Mammals	Human	
Human Activity & Industries	Incinerators and Boilers	Copper Smelters
Human Activity & Industries	Sewage Incineration	Manufacture of Chlorinated Solvents
Human Activity & Industries	Pulp and Paper Mills	Production of Glass
Human Activity & Industries	Cigarette Smoking	Use of Leaded Fuels
Human Activity & Industries	Application of Agricultural Pesticides	Coal Combustion

Agriculture and Climate Change

Humans, like all animals, are driven by their food supply. The world population now exceeds 5 billion and is projected to reach 8 billion by the year 2025. The demand for food increases with population growth and results in more forests felled, more fields cleared and abandoned, more ecosystems impoverished, more soils depleted, more air and water polluted, more energy consumed, more water and fertilizers used, and more greenhouse gases released into the atmosphere.

Scenario Reference

#4 , How will agriculture in the Great Lakes region be affected?

Earth Systems Understandings

This activity focuses on ESUs 3 (science methods and technology), 4 (interactions), 5 (change through time) and 7 (careers and hobbies). See Framework for complete reference.

Agriculture is a widespread and important activity, supplying food and fiber, and providing a livelihood for millions of Americans, both directly (on the farm) and indirectly (processing, transportation, marketing, service industries, etc.). One critical facet of agriculture is the production of corn, wheat and soybeans — our main food crops. Production of these three crops takes up about two–thirds of the total U.S. agricultural acreage, and their economic value is equal to that of all other crops combined. For this reason, these are the crops on which climate modeling efforts have been concentrated.

Part of the Great Lakes Region lies within the Corn Belt where corn and soybeans are primarily produced. But what is the Corn Belt? The U.S. Corn Belt is also known as the country's "agricultural heartland," as it is where the majority of corn, soybeans, and wheat are grown. Technically defined as including the states of Illinois, Indiana, Iowa, Missouri, and Ohio (and also parts of Wisconsin, Nebraska, Kansas, South Dakota and Michigan, North Dakota, and Minnesota), it covers over 700,000 square miles. In Ohio 57 percent of the state's land is used for farming, while Indiana and Illinois have 69 percent and 78 percent, respectively, of their state's land used for farms. A farm generating more than $1000 in sales is considered farmland.

The U.S. Corn Belt is also known as the country's "agricultural heartland," as it is where the majority of corn, soybeans, and wheat are grown.

Corn is the third largest crop in the world, following wheat and soybeans. In the United States, where it is the number one crop, corn is used for animal feed and processed foods such as cereals, corn syrup, corn oil, and corn starch. In other countries, it is used as a main staple in the human diet; for example, in flours and as a vegetable. Industrial uses include alcohol, adhesives, paper, linoleum, paint, soaps, and textile sizing. As corn has been bred by humans for grain production for 25,000 years, we have had a long time to become dependent on corn for many things!

Agriculture is an activity that is very sensitive to climate, because plant growth is directly dependent upon climatic conditions. If global climate changes are substantial, the predicted fluctuations in temperature and moisture conditions will move the major growing areas of the country away from their present

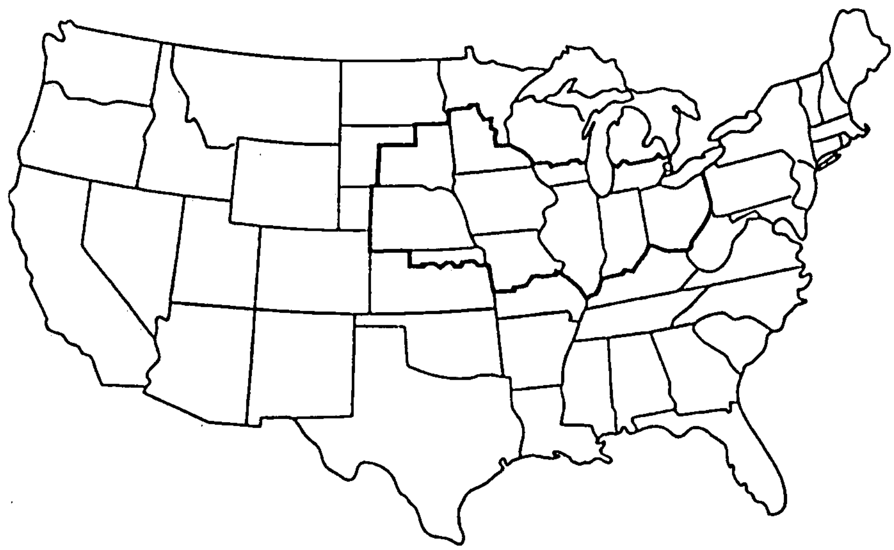

Figure 1. The bold solid line outlines the North American Corn Belt (adapted from Blasing and Solomon, 1983)

locations. Corn crops would generally shift northward (see Figures 1 and 2) and could be replaced by crops of soybeans, cotton, canola, sorghum, barley, and oats. Several crops would also be displaced by the northward shift. These include wheat, hay, and oats.

Production of corn, wheat, and soybeans takes up about two-thirds of the total U.S. agricultural acreage, and their economic value is equal to that of all other crops combined.

Global climate changes would also cause a variety of other changes. A longer growing season would be likely, and this would create a need for crop geneticists to develop new plant varieties. Secondly, as insects and disease pathogen populations are expected to increase, losses of corn yield could be approximately 35 percent unless insecticide and herbicide use is correspondingly increased. Thirdly, if the amount of CO_2 in the atmosphere were to increase as most scientists predict, more carbon would be available for plants as food (carbohydrate) production. As a result, the rate of photosynthesis may increase in some species, producing higher crop yields. For example, corn and sugar cane respond very mildly to elevated levels of CO_2 while wheat, potatoes and beans may increase their growth and yield by 10 to 50 percent. Although yields may be higher with

more CO_2, food quality could deteriorate. In addition, because pests and weeds would thrive in the warmer temperatures and higher CO_2 levels, it is difficult to predict the overall total change in agricultural production in the northern Great Lakes regions.

Although global warming is likely to affect agriculture in the Corn Belt, the economic impact of global warming in the Great Lakes region is a complex issue. Farmers will not necessarily lose money, because other crops may replace current ones, resulting in more, less, or equal profit. Some regions may be harmed economically, while others actually benefit from global warming. There are many factors to consider when thinking of agriculture and global change.

Global climate change could produce a longer growing season, a longer season for insects and higher levels of CO_2 for photosynthesis.

Activity A: Will the Corn Belt be tightened?

Students may have heard adults speak of tightening their belts when economic times get hard. The idea applied to this activity is that there could be less to eat. Is it likely that agriculture in the Great Lakes region will be negatively impacted by global climate change?

Teacher's Note

Have students refer to the appendix following this activity that lists some of the possible characteristics of climate change and their effects on crop production.

Objectives

When students complete this activity, they should be able to:

- Describe how global climate change will affect the agricultural crops currently grown in the Great Lakes states.
- Hypothesize about the crops that could replace those currently grown in the Great Lakes states.
- Discuss the potential economic impacts of global warming on agricultural production in the corn belt.
- Analyze the potential impact of global climate change on people's occupations related to agriculture in the Great Lakes states.
- Articulate the complexity of the relationship between global warming and agriculture, and the resulting difficulty in making predictions.

Materials

For this activity you will need:

- A copy of Figures 1 and 2 for each group
- U.S. Atlas and Almanac, and state maps
- Overhead transparencies and markers
- *Wall Street Journal*
- Appendix: Factors to consider for brainstorming — included with this activity

Procedure

Students will work in groups of four to six to do the following:

1. On a map of the U.S. (Figure 1), note the outline of the present Corn Belt. Using information from an atlas, calculate the approximate area in square miles of the Corn Belt.

2. In Figure 2, each scenario is based upon a 3°C temperature increase. Scenario B is also based on a projection of an 8 cm yearly increase in precipitation; however, this includes a 0.6 cm decrease from July–August. Compare the two models. How does this seasonal precipitation fluctuation affect the range of the Corn Belt?

3. Using either of the Scenarios in Figure 2 and an atlas for reference, what is the estimated approximate area of the projected future Corn Belt?

4. Choose one Great Lakes state and do research to find out the agricultural crops grown there. Consult an almanac or Farm Bureau reference for information about each Great Lakes state. If crops change with global warming, how will the state's economy be affected? Do you think the overall agricultural yield will go up or down?

5. What will be the impact of global change on agriculture? Will the nature of food supply change in the Great Lakes?

6. Do all crops provide equal income to farmers? Using Tables 1 and 2, students should brainstorm possibilities and support their conclusions.

7. What other crops can replace corn? What crops would be displaced by a northward shift of corn?

8. Choose a way in which to present your research to the class. You may use any visual means of your choice (video, computer, slides, overhead transparencies, chalkboard, posters, etc.). Explain which model you used (Figure 2) and why you chose it. Explain your estimates of loss or gain in production, and your predictions of the effects of global climate change on agriculture in one Great Lakes state based on the model you chose, and the information you found. Develop and present a brief summary to the class.

Answers to Procedure

1. Table 3 gives students square miles of each state and projections of area within future corn belts. Students estimate the area of each state within the present corn belt.

2. The seasonal precipitation fluctuation removes North and South Dakota and much of the Great Lakes shoreline resulting in a smaller Corn Belt. This suggests that the timing of rainfall is very important in the growth cycle of a corn plant. Rains in July and August are important for the reproductive stage of the plant's life — tasseling, pollination, and formation of the ear. Harvests would be smaller with the lower rain unless the crops were irrigated. Given the costs of irrigation, lower rains during these critical months could affect crop growth in the northern regions.

3. Figure 2a appears to encompass more land area than 2b suggesting that changes in both precipitation and temperature would affect the new corn belt. The approximate area of the corn belt based on 2a is 300,777. Scenario 2b has an area of 248,015.

4. Students may assume that the state will suffer economically, but some states could increase crop yields and profits.

5. Use "Factors to Consider for Brainstorming" at the end of the activity to examine possible effects of climate change on agricultural crops.

6. See the Teacher's Note accompanying the Extensions and the important factors listed at the end of this activity.

7. Students should see a county agent regarding crops suitable to their area. If new environmental conditions are as predicted, corn crops could be replaced by soybeans, cotton, canola, sorghum, barley, and oats. Crops that would be displaced by a northward shift are wheat, hay and oats.

Figure 2a. Geographic shift of the Corn Belt projected with a 3° C temperature increase evenly distributed over the year and with no change in precipitation (adapted from Blasing and Solomon, 1983).

Figure 2b. Geographic shift of the Corn Belt projected for a 3° C temperature increase evenly distributed over the year and an 8 cm increase in annual precipitation, but with July–August precipitation 0.6 cm less than current values (adapted from Blasing and Solomon, 1983).

*Table 1. Comparison of grain prices (*Wall Street Journal, *November 11, 1993)*

Grain	Month (1994)	Settle Price
CORN (CBT) 5,000 bu.; cents per bu.	March	285 1/4
	May	287 3/4
	July	287 3/4
SOYBEANS (CBT) 5,000 bu.; cents per bu.	March	688 1/2
	May	690 3/4
	July	692 1/2
WHEAT (CBT) 5,000 bu.; cents per bu.	March	340
	May	329 1/4
	July	321 1/2
OATS (CBT) 5,000 bu.; cents per bu.	March	143 3/4
	May	146 3/4
	July	149

The settle prices are read as cents per bushel, for example, a price for wheat of 340 translates to $3.40 per bushel when bushels are sold in groups of 5,000 (a bushel is equivalent to 8 pounds of grain). Grain buyers and sellers make contracts on future grain prices based on predictions. The news issue is from 1993, but prices reflect projections for 1994. Students can obtain more current commodity price information in *The Wall Street Journal* Commodity Section.

Table 2. Acreage of crops grown in the Great Lakes states [data in 1,000s of acres (1989 Census Data)]

	Soybeans/ Beans	Corn/ Grain	Hay	Wheat/ Grain	Oats/ Grain	Corn/ Silage	Misc.
Illinios	8800	9000	1000	1000		100	100
Indiana	4400	4900	700	600	70	100	
Michigan	1000	2000	1400	400			700
Minnesota	4400	4800	2400	2400	700		800
New York		600	2300		200	500	300
Ohio	3700	3100	1300	800	200	200	
Pennsylvania		1070	1915	186	243	438	89
Wisconsin	29997	2788	4784		679	667	329

1993 State of Ohio Average Yields	
Wheat	52 bushels/acre
Soybeans	40 bushels/acre
Corn	140 bushels/acre

Ohio State Extension, Franklin County, OH.

"Success in adapting to possible future climate change will depend on a better definition of what changes will occur where, and on prudent investments, made in timely fashion, in adaptation strategies"

(Rosenzweig and Hillel, 1995).

Answers to Review Questions

1. Difference in climate could move growing areas for corn, soybeans, and wheat away from present locations, causing farming communities to switch to other crops that would be more suitable to the new climate.
2. Genetically engineered plant varieties might require less water. Increase in pesticide use could offset larger insect populations, and irrigation could compensate for drier conditions.
3. Have students look in *Wall Street Journal* for current cost prices.
4. Students should think broadly, to include chemical company jobs, farm machinery repairs, crop storage, insurance, telecommunications, farming–supported industries, laboratory scientists, etc. THey shoulld also consider loss of forests in Minnesota, Wisconsin, Michigan which could be cleared for crops.

Review Questions

1. What could global climate change do to the three major food crops produced in the U.S.?
2. How might advances of agriculture and technology curb crop loss?
3. Evaluate possible replacement crops for those currently grown in the Great Lakes states. What is the comparative economic analysis of these current agricultural crops with the replacement crops (will the new crops result in economic gain)?
4. How might global climate change affect the vocations of those living in the Great Lakes states? What occupations and/ or careers would be gained or lost if global warming caused a decrease in corn production?

Extensions

These extensions can be done individually or in a group.

1. Using the information in Table 1, consider the following:
   a. How do you think this chart would look 50 years from now? 100 years from now?
   b. If less land is available for irrigation, i.e. less cropland, how will this affect prices?
   c. How will farmers' incomes change? How will they have to change their operations, equipment, seed costs, labor, and other costs of doing business?

2. Do "grocery store research" and bring in food products made with corn (meal, flour, syrup, oil, etc.). Find similar products in which other items are substituted for corn. Compare the alternatives on cost, shelf life, and uses.

3. Find some recipes that use corn products. Experiment with other recipes, or create your own, that substitute other ingredients for corn. How do they compare in taste, availability of ingredients, cost and ease of preparation?

4. Imagine you own a 200 acre farm in any one of the Great Lakes states, and you currently raise corn and soybeans there. Describe your farm or draw a diagram showing the current production of crops. Then decide how you will meet changing climate conditions by: a) irrigating, b) changing crops, c) making no changes, etc. Describe your farm–in–the–future or make a new diagram of your farm showing these changes. Transparencies can be used as overlays to illustrate changes.

Teacher's Note

It is difficult to address the question of economics. Different crops have different input costs, which makes it challenging to try to compare one to another. The most profitable crops are not necessarily those with the highest price per bushel. A suggestion would be to assume equal input costs and compare which crops would be most profitable. Then in review it would be important to discuss that in reality these costs vary from crop to crop. Of course, the number of bushels per acre for any crop depends on the crop and the growing conditions. As an extension, the students could consider what would happen if crops replacing corn were not grains, but things such as cotton. Allow students to brainstorm possibilites, while supporting their conclusions. Additional information useful to discussions is included under "Factors to consider for brainstorming."

Further Investigation

One of the important considerations of agricultural production is a plant's characteristics. Plant species conduct photosynthesis differently. Students could do an investigation of photosynthesis to understand the difference between C3 and C4 plants. These values help describe the number of carbon atoms involved in the first step of photosynthesis. C4 plants, such as corn, use CO_2 more economically than C3 plants, such as wheat and soybeans. Increased levels of CO_2 change the competition between these plants, however, making the C3 plants able to better utilize the higher gas levels, as predicted for a changing climate. The following article offers an explanation of this and other related concepts.

Rosenwig, Cynthia and Daniel Hillel. 1993. Agriculture in a Greenhouse World. *Research and Exploration.* Vol. 9, No. 2. pp. 208-221. This is published by the National Geographic Society, Washington, DC.

Factors to Consider for Brainstorming

Effects of Higher CO_2

- Higher levels of atmospheric CO_2 may increase plant growth, resulting in increased yields of corn, soybeans, and wheat.
- Plants may adapt to the gradual change in CO_2 over time, and therefore not alter current production levels.
- Soybeans and wheat tend to respond better to higher CO_2 levels than do corn and sugar cane.
- Corn crops would generally shift northward (see Figures 1 and 2) and could be replaced by crops of soybeans, cotton, canola, sorghum, barley, and oats.

Thermal Changes

- Increased yields may occur in the northern latitudes where warmer temperatures result in a longer growing season.
- Decreased yields may occur in mid–latitudes as higher temperatures shorten a crop's life cycle (shorter time for grain to develop).
- A northward shift of growth zones is expected. Hotter temperatures harm certain crops, such as corn, and they will grow better further north (see Figures 1 and 2).
- Crops, such as soybeans, if they can tolerate heat more easily, may outcompete the corn where it grows now.
- High daily maximum temperatures may affect crops. Hot night temperatures are also bad for corn.

Hydrological Change

- Rainfall patterns will change, which might expand crop irrigation requirements in certain regions. Along with a reduction in water supplies, the extra water demand may require some land to be removed from irrigation. Water resources are already tight in some areas because of urban demands.
- With less precipitation, drier soil is likely.
- Dry periods may be particularly harmful during grain–filling stages of plant growth.
- It may be necessary to breed crop varieties that are drought resistant as well as heat resistant.

Climate Variability

- Extreme events are possible — droughts, extremely high or low temperatures, and storms.
- Variations may push crops over their temperature tolerance.

Pests and Diseases

- Global warming may change the ranges and populations of agricultural pests. New approaches to pest control may be needed.
- With warmer temperatures, insects may survive the winter and have longer reproductive cycles, resulting in larger populations.
- Predators of insects may also have longer reproductive cycles
- Warmer temperatures may favor some plant diseases that would normally occur in the subtropical region but could flourish in the new climate of temperate zones.

Soils

- Warmer temperatures may mean increased decomposition by microorganisms and decreased fertility, thus less nutrients in the soil.
- More fertilizers may be needed.
- Soils may be drier and more prone to wind and rain erosion, particularly during storms.

What can you hypothesize about crop production in the Great Lakes region based on these possibilities?

Table 3. Total area of states and two scenarios of geographic shift

State	Total Sq. miles	Total Corn Belt Sq. miles	2a Sq. miles	2b Sq. miles
Illinois	56,345	56,345	21,580	25,500
Indiana	36,185	36,185	20,300	36,185
Iowa	56,275	56,275	20,000	25,000
Kansas	82,277		0	0
Michigan	58,527		58,527	0
Minnesota	84,402		73,000	64,860
Missouri	69,697		0	0
Nebraska	77,355		0	0
North Dakota	70,702	0	21,750	0
Ohio	41,330	41,330	25,080	41,330
South Dakota	77,116		4,500	0
Wisconsin	56,153		56,040	55,140
Totals	766,364		300,777	248,015

Selected data taken from the1994 World Almanac.

References

Blasing, T.J. and A.M. Solomon. 1983. *Response of the North American corn belt to climate warming.* U.S. Dept. of Energy, DOE/NBB-0040. Washington, D.C.

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Great Lakes Shipping and Lowered Lake Levels

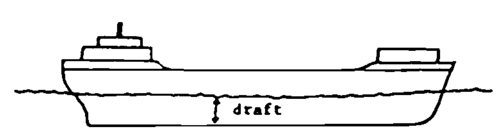
The Great Lakes have been used as an avenue of transport for goods of all types for hundreds of years. Native Americans, French voyagers, and early pioneers used the lakes to move goods easily from one point to another. Today, nearly 200 million tons of cargo are shipped on the Great Lakes every year. Coal, iron ore, grain, and building materials such as gravel and cement are shipped in bulk. It is the most economical way to ship large quantities of products. However, there are limitations involved in the shipping industry. The formation of ice on the lakes cuts the shipping season by about two months per year. Another limiting factor is water levels. The Great Lakes' levels fluctuate seasonally and are sensitive to differences in rainfall and evaporation rates which can change from year to year.

Many areas in the Great Lakes are shallow and thus must be dredged seasonally to keep the water levels deep enough for the loaded vessels to pass safely. Many harbors and the locks and canals, as well as the entire western basin of Lake Erie have barely enough water depth to allow fully loaded vessels to pass under normal conditions. Often cargoes have to be lightened because of lower lake levels that result from periodic droughts.

But what if there were a major drop in lake levels that persisted for a long time? Climatologists, using computer models, have indicated that because of the greenhouse effect an atmospheric warming of up to 4.5°C could occur by the year 2055. This would cause very high rates of evaporation in the Great Lakes Basin, lowering the levels of the lakes by as much as 3 m. Such a drop could have serious effects on the shipping industry. On the other hand, warmer temperatures could lessen the impact of winter on the industry — perhaps shipping can continue year–round, making up for losses at other times of the year.

This set of activities will help to show the dramatic changes that can be expected in the critical shipping sector of the economy. Students should be alert to both positive and negative aspects of the changes anticipated.

When a ship is fully loaded, it floats lower in the water than it would with a lighter load. The depth of water displaced is called the draft of the vessel.



Activity A: Will global warming change the economics of the shipping industry?

Changes in lake levels will impact the shipping industry. How much? Will losses be offset by gains in length of season or changes within the industry? This math activity sets the stage for discussion of shipping futures.

Earth Systems Understandings

This activity focuses on ESU #3 (science methods and technology), #4 (interactions), and #7 (careers and hobbies). For a complete listing of the Understandings, see the introduction to this book.

Scenario Reference

#3, What could happen to Great Lakes Shipping?

Materials

- calculator
- copy of the "Impact of Lake Levels on Vessel Carrying Capacity" chart.

Answers

a. 22,064 T x $2 per ton = $44,128

b. 24 inches x 107 tons/inch x $2/ton – $5136 lost per trip. This would be a serious loss, cutting revenue by more than 10 percent.

Objectives

Students completing this activity will be able to:

- calculate the potential loss of revenue for ship owners if lake levels drop;
- evaluate the economic impact of a shipping season increased to year–round;
- describe the overall economic impact on the Great Lakes shipping industry.

Procedure

1. Examine the data table, noting the following:
   - *Vessel Length* indicates the five common lengths for Great lakes freighters.
   - *Per Trip Carrying Capacity* tells what net weight (cargo only) the freighter can haul.
   - *Capacity Per Inch of Draft* indicates how many extra tons of cargo the vessel would be carrying if it were loaded so that it floated one inch lower in the water.

2. Use the data table to answer the following questions.

   a. A small shipping company uses one of its smaller vessels, 635 feet long, to supply coal from Toledo to Detroit. They charge $2 per ton for this service. How much would they charge for the full load of coal?

   b. How much would the company lose per trip during a drought if the lake level went down two feet and they had to reduce their cargo level? Would these losses have a serious effect on a small shipping company?

Impact of Lake Levels on Vessel Carrying Capacity
(net tons)

Great Lakes Bulk Carriers	Vessel Length (feet)	Per-trip Carrying Capacity	Capacity Per Inch of Draft*
	1,000	69,664	267
	806	34,720	146
	767	28,336	127
	635	22,064	107
	501	13,776	71

* Capacity per inch of draft reflects the incremental tonnage carried at normal loaded draft.

c. An average charge for a shipping company is $6 per ton for carrying iron ore from Duluth, Minnesota, to Cleveland, Ohio. If a company used a 1,000-foot vessel, how much would the total charge be for the trip?

c. 69,664 tons x $6/ton = $417,984

d. Would this be pure profit for the owners? Explain.

d. Fuel costs, debt service, salaries for sailors and office personnel, insurance premiums, upkeep on the vessel would have to come out of these revenues.

e. Imagine that lake levels dropped by 8 inches. How much less revenue would the company earn per trip in a 1,000-foot vessel?

e. 8 inches x 267 tons/inch = 2136 tons less. 2,136 tons x $6/ton = $12,816 less per trip

f. In the global climate change worst case scenario, the atmosphere warms dramatically and the lakes drop 10 feet. How much would the shippers lose per trip in this situation? Would the trip be possible?

f. 120 inches x 267 tons/inch x $6/ton = $192,240 per trip loss

g. Many industries in the U.S. and Canada, as well as in other parts of the world, rely on the materials shipped on the Great Lakes. The Lake Carriers would need to charge more per ton of goods delivered if they had to carry less per trip because of lower water levels. What types of goods could we expect to increase in price because of this? Discuss with the class how all our lives would be affected by this change.

g. Products dependent on grains (cereal, bread, animal feed), steel products, coal and oil (energy costs), building materials would all increase in price. This could cause people to buy lower-priced imported goods.

h. $93,000,000 to $124,000,000

h. The companies that are members of the Lake Carrier's Association own a total of 62 vessels. The average number of crew members per vessel is 28, but a total list of 42 must be available to cover vacations and sick leave. Office personnel for the entire association numbers around 500. If all of these workers receive salaries at about the U.S. average of $30-40,000, how much would their yearly gross be?

i. Many products would be in short supply and prices would rise significantly on many products.

i. Consider all of the industries totally or partially dependent on Great Lakes shipping and the employees of the shipping industry. How would you characterize the effect that global climate change might potentially have on economies in general?

IT WOULD BE SIMPLE TO CONCLUDE FROM QUESTIONS 1-4 THAT SHIPPING WILL BE ONE OF THE LOSERS IN THE GLOBAL WARMING GAME. FEW THINGS RELATED TO ENVIRONMENT AND ECONOMY ARE SIMPLE, HOWEVER. THERE ARE MANY OTHER FACTORS THAT SHOULD BE CONSIDERED BEFORE CONCLUDING THAT SHIPPING IS A LOST CAUSE. DISCUSS THE ISSUES ON THE FOLLOWING PAGES WITH THE CLASS TO MODIFY THIS CONCLUSION.

ICE EFFECTS

The scenario up to this point does not take into account the other effects of warming, namely that ice patterns are likely to change, and there may be the possibility of year— round shipping. If goods are shipped and people are paid year— round, the picture might not be so bleak.

j. To convert metric tons to U.S. tons: 69.8 million metric tons x 1.1 = 76.78 million U.S. tons.

To find total U.S. tons shipped in 1992: 105.8 + 76.78 = 182.58 million U.S. tons.

To find total 12–month potential: 182.58 / 5 = 36.516, then 36.516 x 6 = 219.096 million tons.

j. The volume of shipping in 1992 was about 105.8 million tons for U.S. flag vessels and 69.8 million metric tons for Canadian flag vessels. One metric ton (or *tonne*) equals 1.1 U.S. tons. Calculate the total weight of Great Lakes shipping in the ten month 1992 season. This is theoretically 5/6 of what it could be if the lakes were ice–free or at least passable all year. Find the potential shipping volume for a 12–month season.

Of course other costs would also expand to 12 months. The vessel crews should be paid more per year, and insurance and vessel upkeep would increase as well. Discuss with the class whether a 12–month shipping season would be economically feasible for shippers.

Other Considerations

Shipping is a business, and in the Great Lakes many people depend on it. It is unlikely that as a business it would sit idly by and let the global warming changes destroy its vitality.

k. Brainstorm with the class how shipping can change to accommodate climate effects. Remember:

- Global warming will not happen overnight but slowly and with some sporadic changes as well.
- Technology does not stand still.
- We can only dredge so deep before we hit bedrock in some areas.
- There is no law that governs the size and shape of Great Lakes ships although the size is constrained by the depth, width, and length of channels and locks.
- Shipping is a business and must make a profit to survive.
- Alternative means of cargo transport may also change.
- The channels in the western basin of Lake Erie would need to be dredged in order for the freighter to get to Huron.

Review Question

The shipping industry will face many challenges with global warming. Make a concept map showing the impact of global warming on shipping, and extend the map to include responses by the industry and others in the region. Will shipping be a winner or a loser in the climate game?

Teacher's Note

OEAGLS activities can be obtained from:
Ohio Sea Grant College Program
1314 Kinnear Rd.
Columbus, OH 43212
(614) 292-8949

Extensions

1. Do the OEAGLS (Oceanic Education Activities for Great Lakes Schools) activities related to water transportation:

   EP-013, entitled "Shipping on the Great Lakes" examines the flow of goods from one section of the Great Lakes to another and compares the cost of shipping goods by truck, rail and air.

   EP-020, "Shipping: The world connection" dramatically shows the importance of Great Lakes shipping in world commerce. It examines the extent of trade through the Port of Toledo as an example of the impact of the region, serving nearly two-thirds of the world in one year.

EP-015, The "Ohio Canals" activity details how locks work by having students create a model out of milk cartons.

2. Trace how boats and shipping have changed on the Great Lakes through history. How did different vessel designs adapt to changing water levels before the lakes had locks and dams?

REFERENCES

Cash, Jim. 1994. The current status of shipping on the Great Lakes. The Ohio State University, unpublished MS paper.

Havighurst, Walter. 1975. *Long ships passing*. New York: Macmillan.

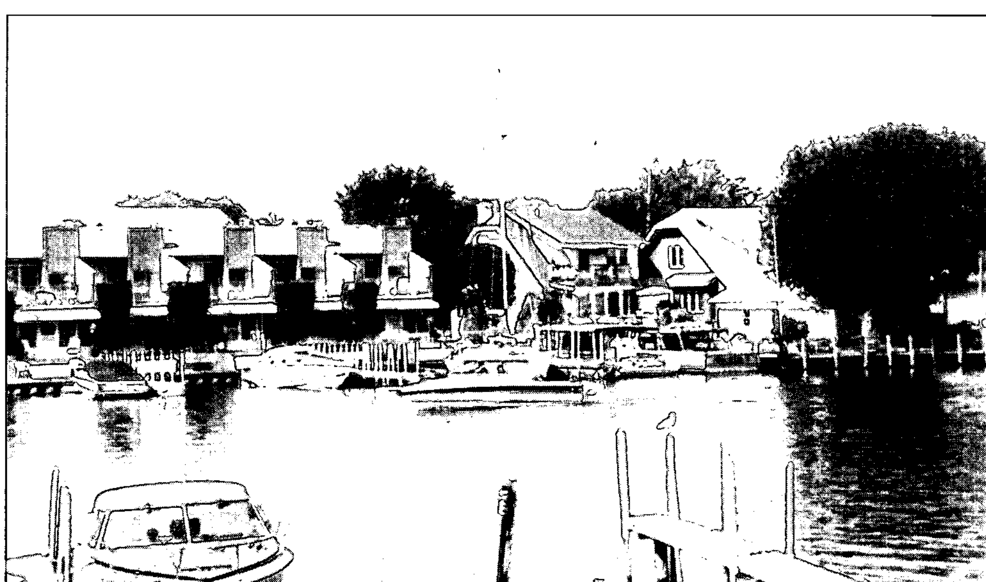
Lake Carriers Association. 1992. *Annual report of the Lake Carriers Association.* Cleveland, OH.

Lesstrang, Jacques. 1985. *Cargo carriers of the Great Lakes.* Boyne City, MI: Harbor House.

Activity B: What economic costs and benefits might coastal communities experience from lower lake levels? (A tale of two harbors)

To people living on the shores of the Great Lakes, the small seasonal fluctuations in the Lakes' levels, measured in inches or a couple of feet at most, are of little concern. Lower levels could mean a slightly wider beach or a few exposed rocks near shore. Slightly higher levels could result in waves lapping a few feet further up the beach toward shore. But what would the effects be if there were a drastic change, several meters, in the water level of the Great Lakes? This activity will explore different ways that a small town might be affected and how it might react.

Many communities are dependent upon the Lakes for recreation, shipping and transportation, tourism, and water supply. These communities could be seriously affected by a major lowering of the Lakes' levels. One such community is Huron, Ohio, located on Lake Erie at the mouth of the Huron River. The Huron River drains an agricultural area with minimal pollution from cities or industry. The town has a population of about 9,000 and has a small port facility for the handling of iron ore, limestone, and grain. It is also a railhead for the further distribution of these products. Important to the local economy are five marinas located within the city limits, serving a large number of Lake Erie recreational boaters.



Earth Systems Understandings

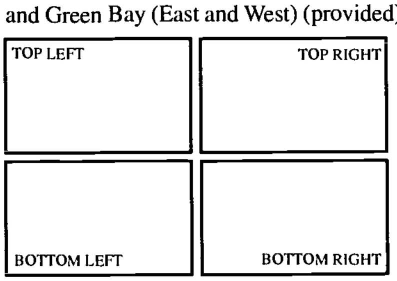
This activity focuses on ESU #2 (stewardship), #3 (science methods and technology), #4 (interactions), and #7 (careers and hobbies).

Scenario Reference

#3, What could happen to Great Lakes shipping?

Materials

- aerial photos of Huron and Green Bay (provided)
- nautical chart and Corps of Engineers fact sheet of Huron Harbor (optional)
- USGS topographic maps of Huron, Ohio, and Green Bay (East and West) (provided)



Assemble Green Bay map as shown.

Another lakeshore community is Green Bay, Wisconsin. This area has been designated as an Area Of Concern (AOC) by the International Joint Commission. The Green Bay area has a population well over 150,000, with the largest concentration of paper mills in the world located along the Fox River. The Fox flows into Green Bay, a large but shallow bay of Lake Michigan. Sediments brought into Green Bay by the Fox River carry toxins such as PCBs, heavy metals, pesticides, and dioxins. The industries causing most of the pollution have existed for a long time, resulting in large accumulations of toxic sediments on the bottom of Green Bay. Some headway has been made in getting cleanup started, but the completed job will take a long time. Add to this scenario the possibility of lowered lake levels because of global climate change, and the city has possibly another very difficult problem. If dredging is needed to deepen the harbor for shipping, some of the toxic-laden sediments could be exposed as dry land.

Both Green Bay and Huron stand to be heavily impacted in a variety of ways, some positive and some negative, if Great Lakes water level drops significantly. In this activity, students may study either community or both. Procedures differ somewhat, but results will be comparable to allow for serious discussion of impacts.

Objectives

Students who have completed these activities will be able to:

- use maps and aerial photos to examine and calculate land area changes
- calculate and interpret some economic costs and benefits of lowered lake levels as they would be felt by coastal cities
- analyze the impacts of lowered lake levels on different lakeshore communities.

Procedures

If both communities will be studied, divide the class in half so that some investigate Huron and others Green Bay. Depending on time and resources available, it may be necessary to limit discussion to only one of the communities. Set up teams or small working groups.

TEACHER NOTE: THE DIRECTIONS FOR THE ACTIVITY ARE WRITTEN FOR STUDENTS. MEASUREMENTS ARE IN ENGLISH UNITS BECAUSE THEY APPEAR ON MAPS THAT WAY. CONVERSION INFORMATION IS PROVIDED AS APPROPRIATE.

1. **Orienting to the area**

Familiarize yourself with the community your team is studying. Look at the aerial photos and the maps provided and answer the following questions. Use map scales as appropriate.

a. What kinds of natural and cultural features do you see? List several. What appear to be the major land uses in the city? Do you see features that could be associated with quality of life in the area? Explain.

b. Approximately how wide is the river where it enters the lake? What kinds of features border the river in its first mile inland?

c. About how many miles of shoreline are bordered by the main part of the city? Is the shore dominated by residences, farms, or other features?

d. What is the maximum depth of the Great Lake in the area of the topographic map segment? What is the depth of the ship channel coming into the river?

a. Alert students to shapes, shadows and layouts of features that indicate such things as schools (with running track), storage tanks, suburban streets, etc. Green Bay appears to have more industrieal development along the shore; wetlands are diked (managed). Huron is residential along most of the shore and has less population density.

b. Huron River: 255 feet wide, bordered by marinas, warehouses (boat storage), and at the mouth some slips for lakers in port. Fox River: about 800 feet wide, bordered by large buildings and grounds (industrial area).

c. Huron: small city, 1-2 miles; residential and natural areas. Green Bay: industry and managed wetlands, also about 1-2 miles visible on these reference images.

d. Huron: 35 feet, ship channel 25 feet
Green Bay: 19 feet, ship channel 24 feet.

2. **Finding the new shoreline.**

If Great Lakes water level were to drop 3 meters (10 feet) or even half that amount in the next few decades as a result of global warming, as some computer models predict, shallow offshore areas would become dry land.

Look at the topographic map of the community and its shore. Measure how much new land will result by using the following method.

a. Find the soundings, marked in feet, out in the lake or bay. All areas that are 10 feet deep or less could eventually become marshland or dry land. Construct a 10 foot depth contour to determine where the new shoreline would be. If there are no 10s to connect, interpolate the depth between soundings.

b. Further out from shore, the water gets deeper and sometimes much shallower again. These shallow areas should be included in your tracings, since they could appear as islands or peninsulas when water levels drop.

Students are allowed to determine for themselves how far to measure. If measuring from the city limits, they could calculate approximately how much shoreline would be added to each city and compare these numbers.

The images included for this activity are from previous years. If students desire more recent photographs, they should obtain them. This will enable them to discover what industries/structures/land use exist currently in these cities.

3. Determining land acquisition.

a. Obtain a transparent copy of the included grid page. Based on the scale of the map, one square is equal to 1,000,000 sq ft (1000 ft x 1000-ft box). Place it over the map of the newly exposed lake bottom (from Part B), and count the squares to determine how far lakeward, on the average, the amount of new land extends.

b. How many square miles of land would the lakeshore city acquire?

c. Notice the difference in scale between the topographic map and the aerial photo of your city. Sketch in the approximate position of the new shoreline on the aerial photo. Estimate how many homes or other property segments in the city would have a "new and bigger" backyard.

d. Try to imagine what the area would look like from the air if the water level dropped 10 feet. Sketch in the new landforms on your copy of the aerial photo.

a. Answers will vary for this, since students will have interpolated the new shoreline differently and will count squares in different ways. Advise them to divide an area into sections for ease of measurement and to count a square only if more than one-half of it includes the new area.

b. Measuring approximately from city limits Huron: 1 sq mile (26 grid boxes) Green Bay: 24 sq miles (334 grid boxes).

c. Answers will vary greatly depending on how the students interpret what kinds of property segments are present. Accept differences and discuss. Discuss the value of "ground truth" for scientists seeking more information about a region than remote sensing can provide.

4. Finding the value of the new land.

Discuss who could or should benefit from the sale of this new land. Should current lakeshore landowners automatically acquire the new land without paying for it? Should the city own it and use it for the good of all? These are questions that people may have to find solutions for in the next few decades.

One factor in the decision will be the property value. In 1993 the value of near-shore property was as follows:

Huron: $250,000 to $300,000 per acre
Green Bay/Fox River: $150,000 per acre

Why do you think the figures are so different? What would be the approximate value of each city's "new land" using these figures?

Conversions:
One sq mile = 640 acres = 27,878,400 sq ft.

While the figures may be related to zoning decisions made by the cities, they may also indicate aesthetic value or desirability for certain uses. The dollar value here should be calculated based on the answer to C2.

5. Keeping the Harbor Open

Great Lakes freighters require a depth of about 25 feet for safe navigation in protected waters such as Huron Harbor. Currently, the Army Corps of Engineers is responsible for the clearing of sediment, brought downstream by rivers, from the harbor and approach channel located in the Lake. This is an expensive procedure requiring the use of a large floating dredge. If lake levels dropped the projected 10 feet, dredging an additional 10 feet would compensate for the lower water levels and would suffice to keep the freighter traffic moving.

a. Using the map provided, find the areas that represent the approach channel and turning basin for lake freighters using the harbor. Also locate the "slips" (docking areas) where freighters load or unload their cargoes of grain, limestone or iron ore.

Answers will vary in this section, but will generally come out to a ratio of 1:4, with Green Bay's challenges and opportunities being four times that of Huron's.

b. With the scale on the map, measure and calculate
   a. average width of entrance channel multiplied by one mile (to cover access to the harbor from the lake)
   b. total area of slips and turning basins in the harbor.

c. Calculate the total square feet of the area that would need to be dredged (approximately).

d. If lake level dropped 10 feet, how many cubic feet of sediment and rock would have to be removed to maintain the depth of the harbor? Charges for dredging are based on how many cubic <u>yards</u> are removed. To convert cubic feet to cubic yards, divide your answer by 27.

e. Dredging first removes sand and mud, but then it may reach bedrock. Dredging sand and mud costs about $5 per cubic yard. However, the present channels are already down to bedrock in most areas. The cost to break up the bedrock and remove it is about $75 per cubic yard. Calculate the cost for dredging if all the dredged material is bedrock.

Remember that in many coastal areas of the Great Lakes the sediments have toxic chemicals in them, and these would be disturbed by dredging. Dredged sediments may be put into a safe disposal site within concrete or steel walls, out from the shore. Both aerial photos show the locations of such containments. Discuss the issues that arise when potentially toxic sediments are stored in this way.

CONCLUSION

These exercises demonstrate some of the types of effects that global climate change could have on shoreline and port communities. Imagine the disruption on a worldwide basis if projected global warming occurs. Remember that in most coastal areas, sea level will RISE, probably with even greater consequences than the Great Lakes drop in water levels will cause. Be sure students discuss the personal life-style changes that would help to prevent global warming from increasing. Activities on RESPONDING will assist.

REVIEW QUESTIONS

1. What are some ways that people living in a lakeshore town such as Huron or Green Bay would be affected by a 3-meter drop in Lake Erie's level? Rank the issues involved on a scale where 10 = most significant. Which of the issues, when resolved, will determine whether the community is a winner or loser in the global warming story?

2. Do you feel that the Federal government would pay the large sum of money needed to deepen Great Lakes harbors? Think of the size of a given harbor, the use it gets, and the large amount of money. If the Federal government wouldn't pay this sum, what would it mean to the port city to lose its shipping terminal and its marinas ?

3. Earth System scientists use data in the form of images as well as numbers. Evaluate the types of images used here for their value to scientists (e.g., what can be learned from them, what advantages do they have over other technologies, what are their limitations?).

EXTENSIONS

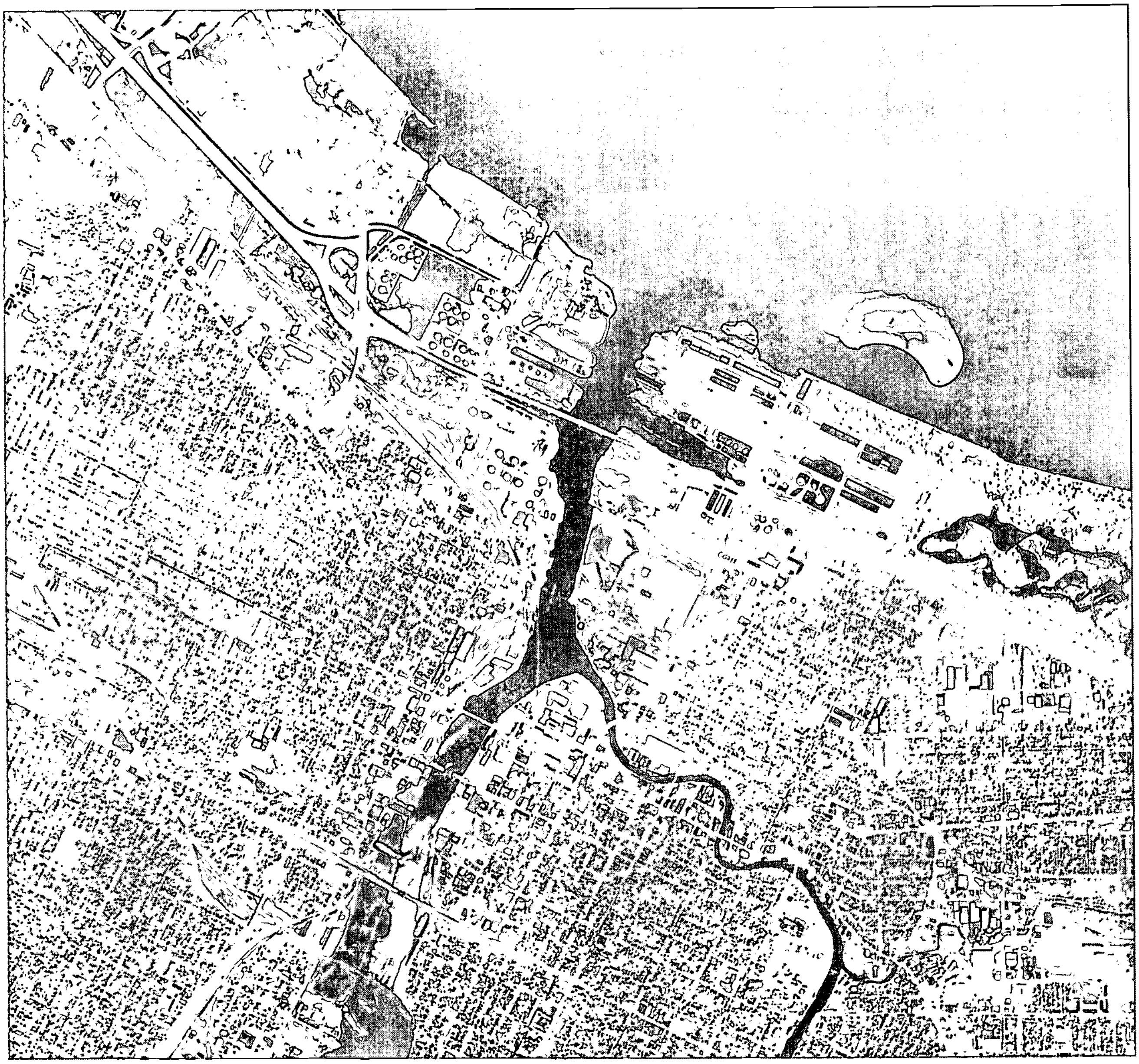
1. Hold a town council meeting with students assigned to represent different interest groups (city officials, local conservation groups, realtors, shoreline homeowners) who would be responsible as a group to decide to what use the "new land" would be put.

2. The marsh areas bordering the Fox and Huron Rivers could become dry land if lake levels drop significantly. Many species of fish use these areas for spawning. How might the Lake's food chain be disrupted if marshes like these disappear? Use activities in other parts of this volume as a start to finding your answers.

3. The Green Bay area communities have developed and are implementing a Remedial Action Plan (RAP) to clean up pollution problems and restore Green Bay to full uses of the water. Write to the Wisconsin Department of Natural Resources for information about the status of the RAP, and discuss the difficulties of implementing such a plan.

Information sources

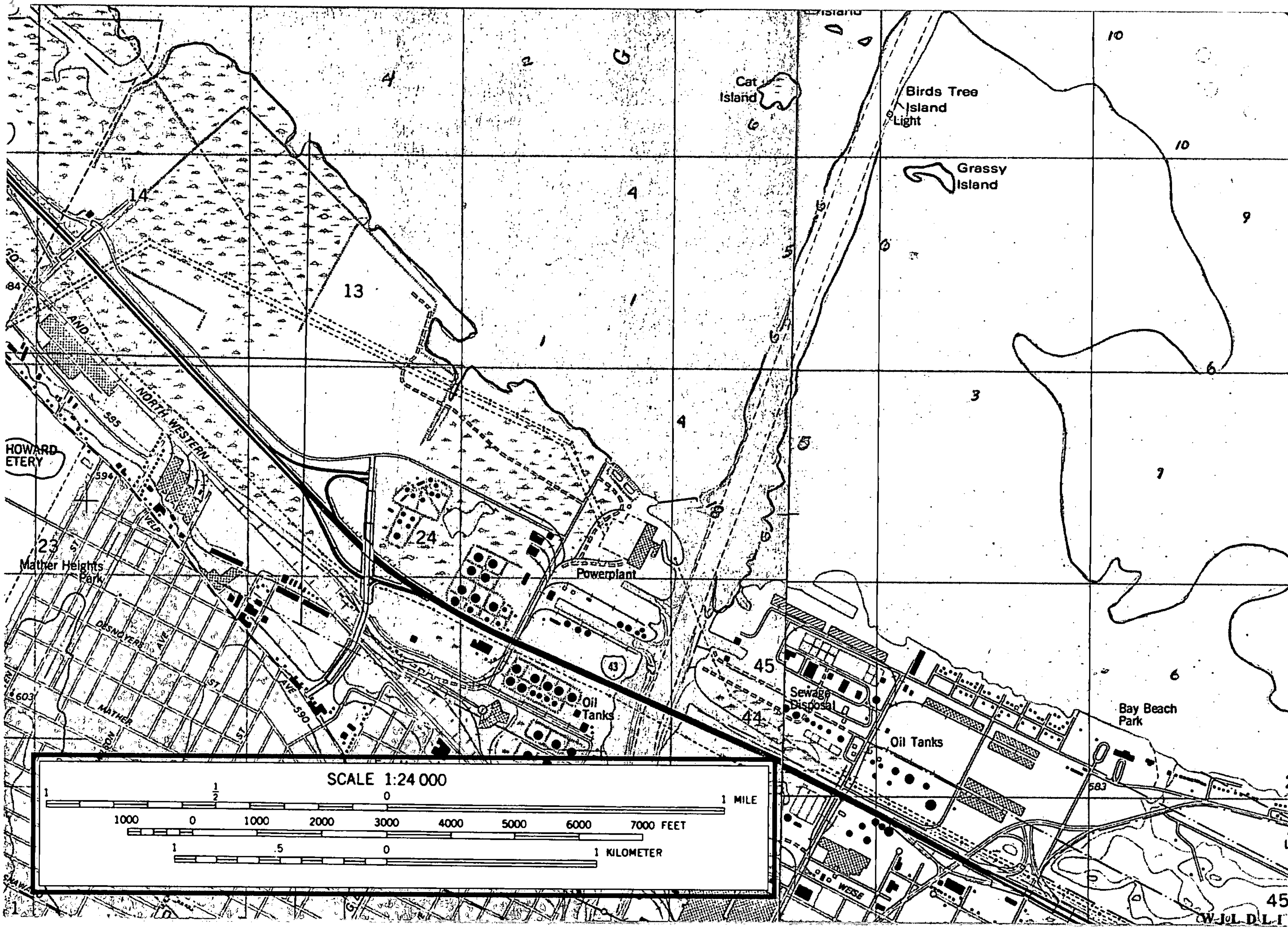
- City Hall, Huron, OH
- U.S. Army Engineer Districts, Buffalo and Detroit
- Green Bay RAP



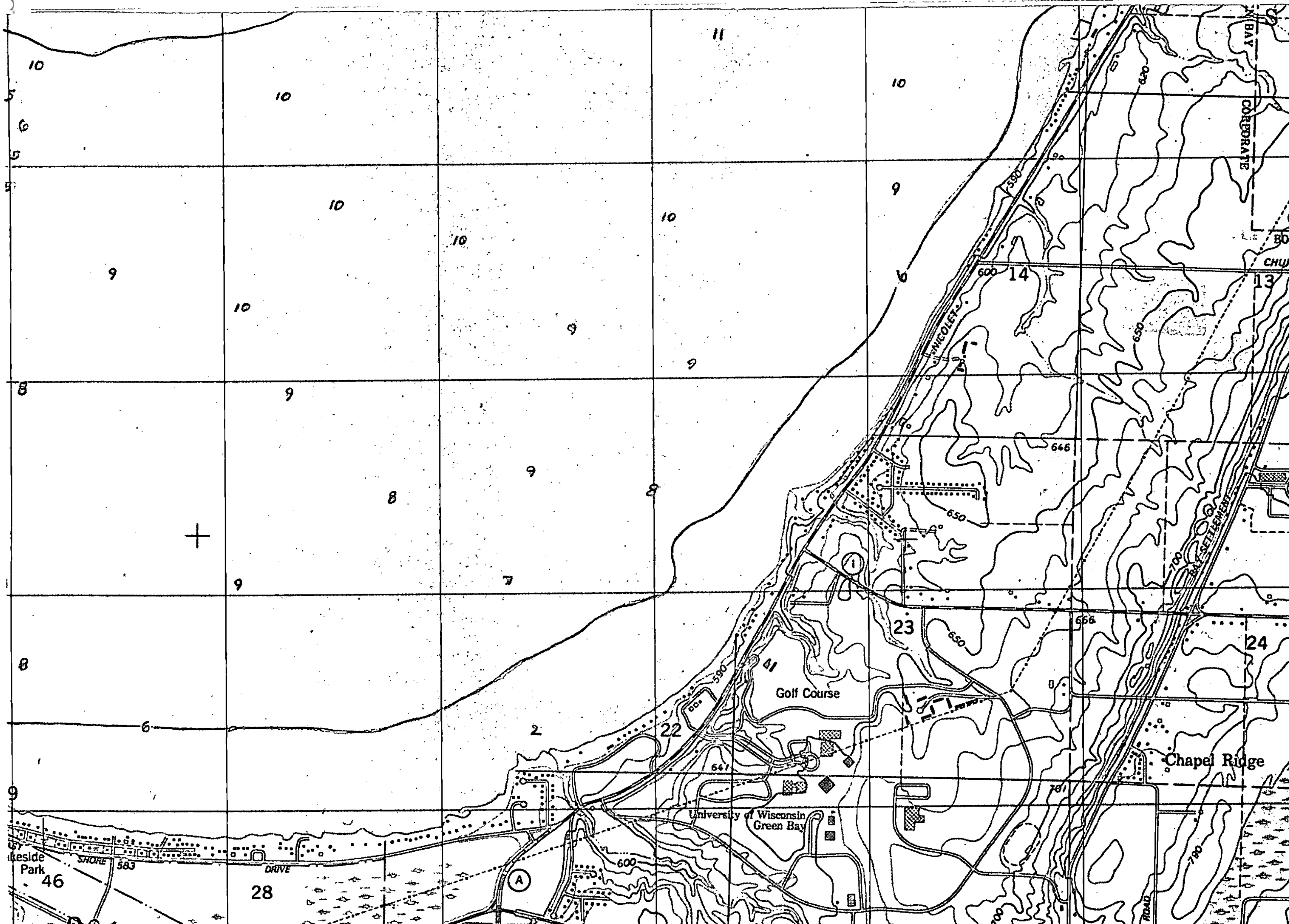
Green Bay aerial view

B

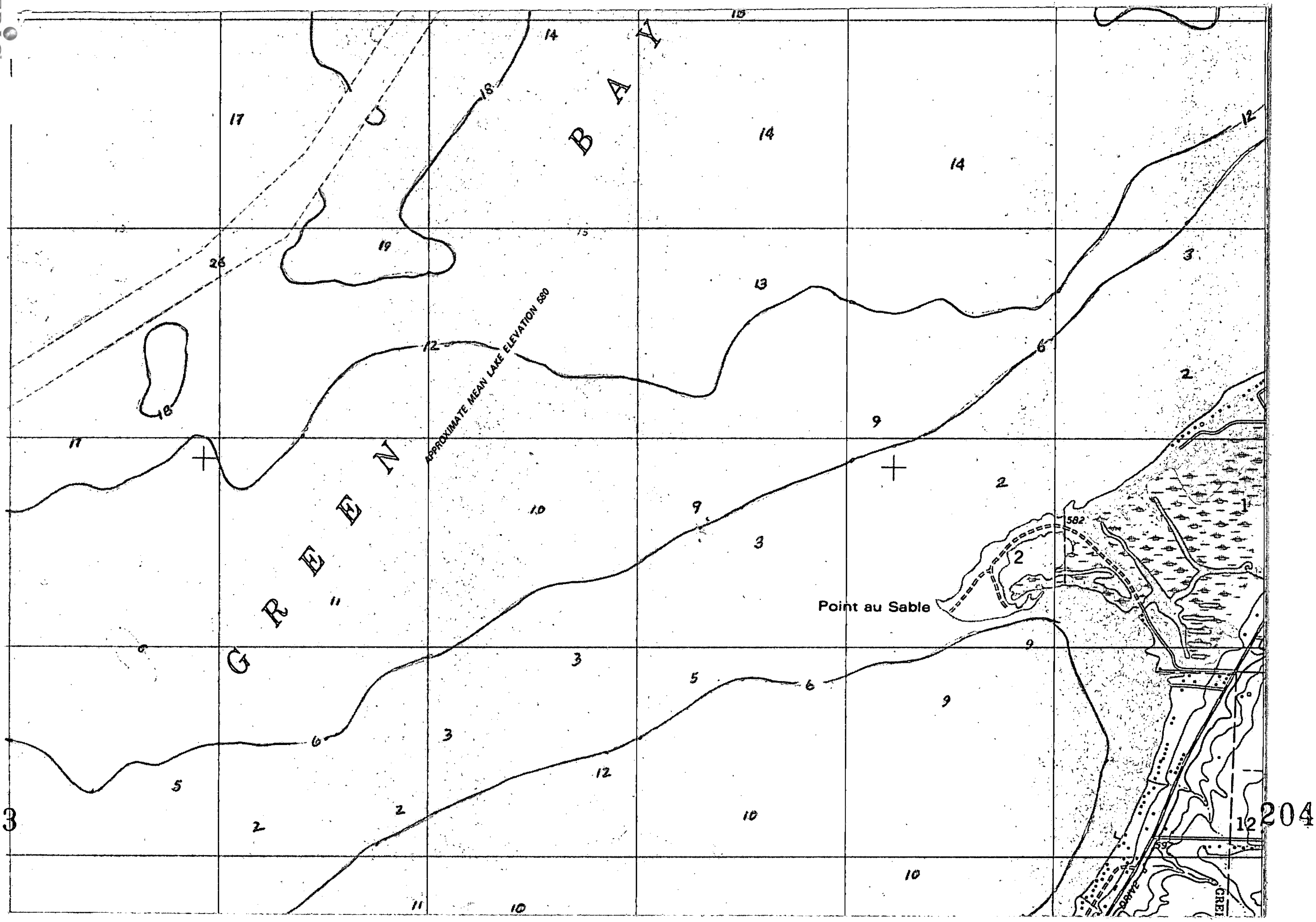
D



BOTTOM LEFT/ GREEN BAY

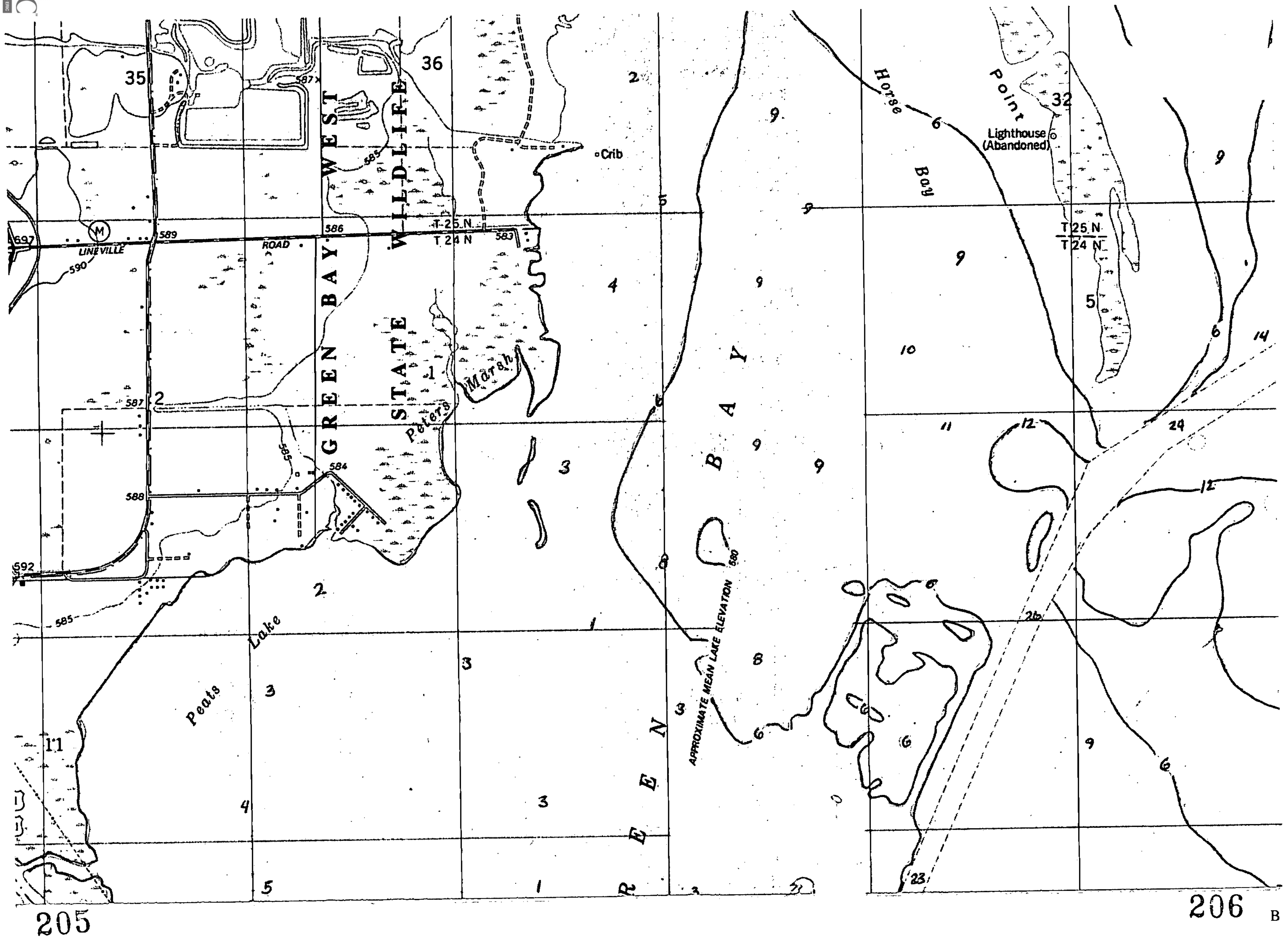


BOTTOM RIGHT/ GREEN BAY

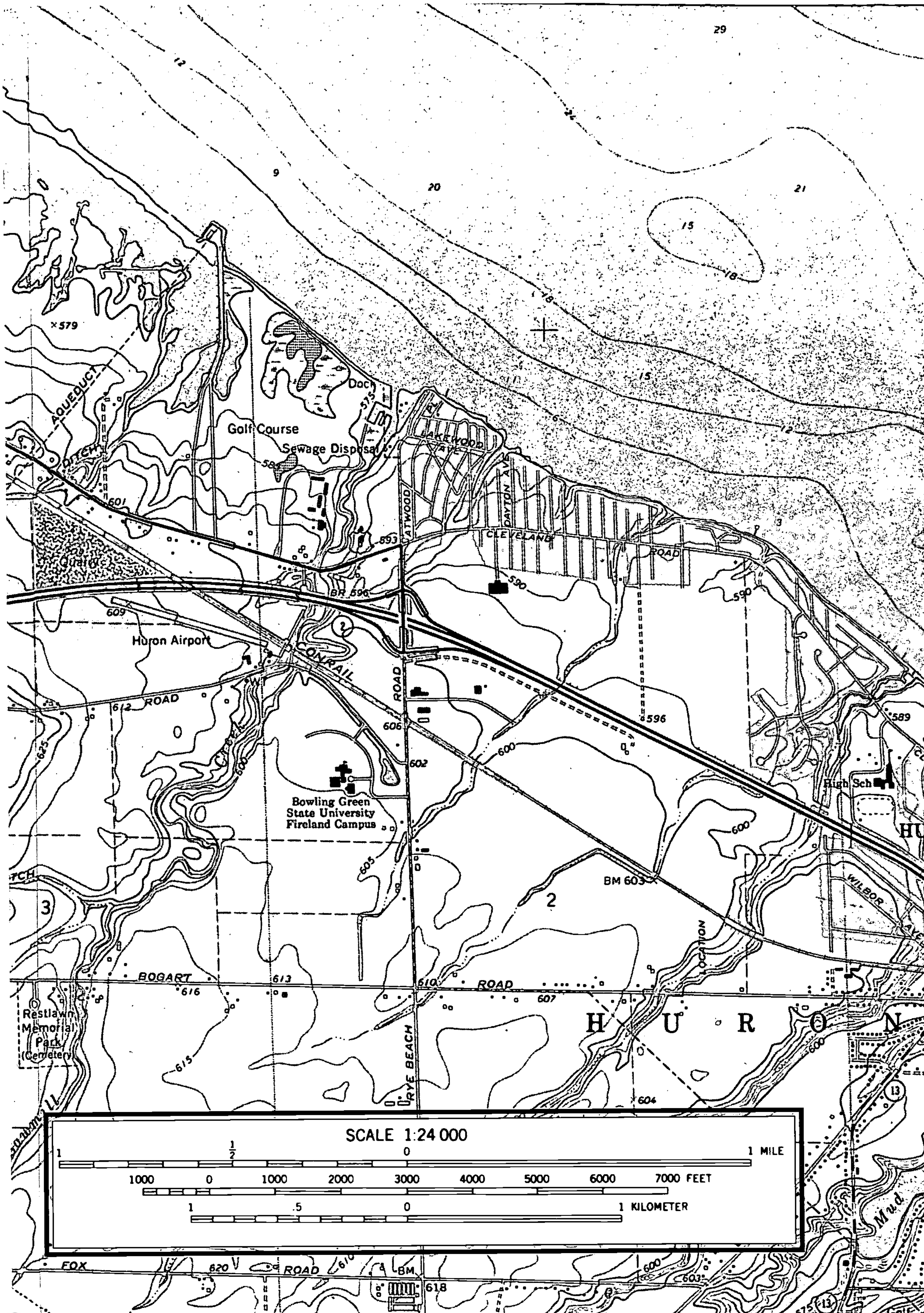

GREEN BAY
APPROXIMATE MEAN LAKE ELEVATION 580
Point au Sable
582
203
204

A

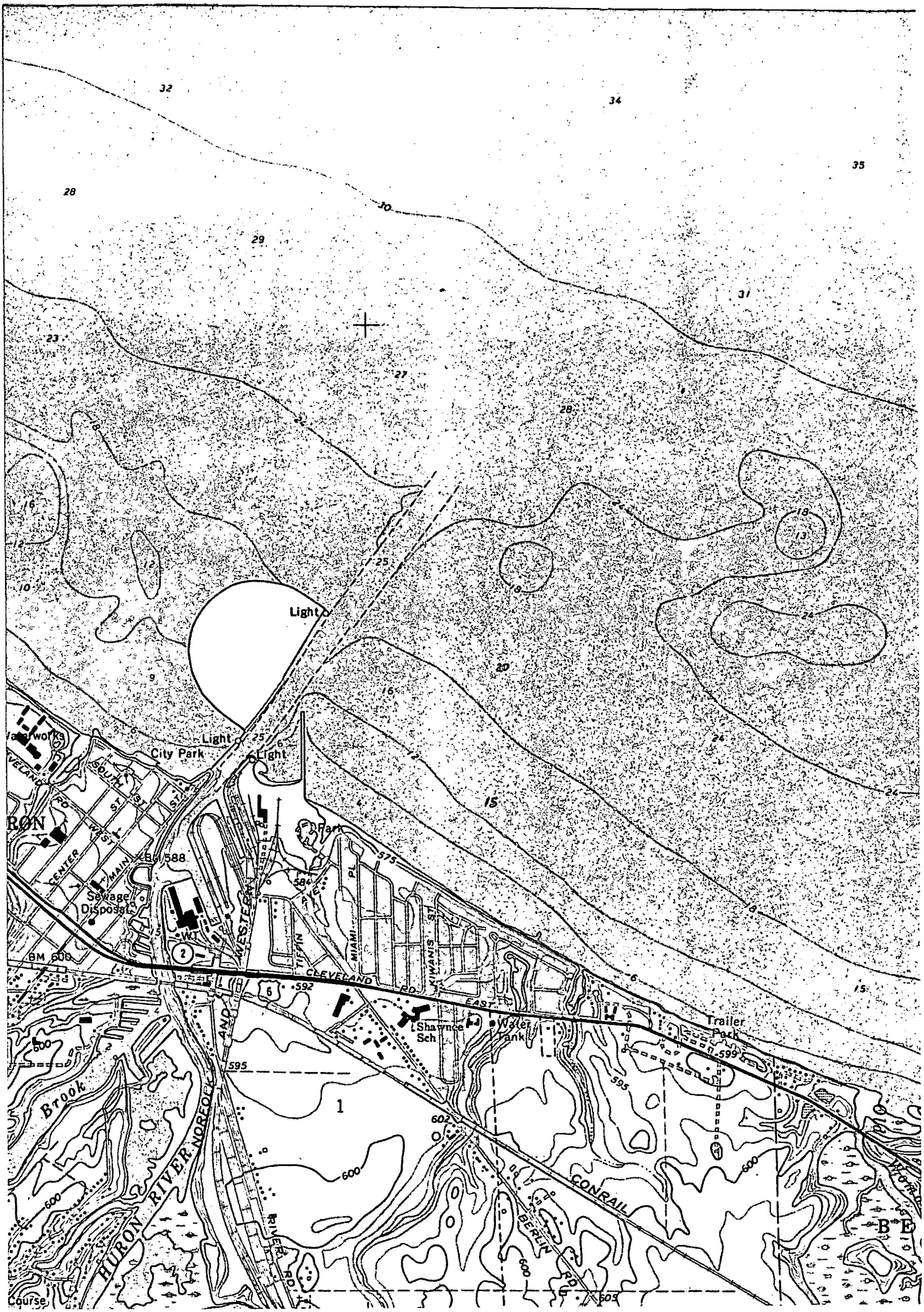
C


GREEN BAY WEST STATE WILDLIFE
GREEN BAY
Horse Bay
Point
Lighthouse (Abandoned)
Crib
Peters Marsh
Peats Lake
LINEVILLE ROAD
APPROXIMATE MEAN LAKE ELEVATION 580
T 25 N
T 24 N
35
36
32
205
206

Huron aerial view



TTOM LEFT/ HURON



BOTTOM RIGHT/ HURON

Activity C: How can we map changes in water level?

The current concerns with global warming have prompted an awareness of secondary problems such as changes in water levels of major lakes and oceans. We can address this problem with an activity designed to increase student awareness of the effects of changing water levels. This activity is also helpful in teaching students how to interpret and use contour maps.

Earth Systems Understandings

This activity addresses ESU #3 (science methods and technology) and #4 (interactions). Refer to the introduction of this book for a full description of the understandings.

Global Change Scenario

#1, What will happen to water resources?

Objectives

When students have completed this activity, they will be able to:

- create and interpret a contour map;
- describe how contour maps can be used to study changes in water levels and land elevations;

Procedure

1. Cut off the top of a 2-liter bottle about 15 to 20 cm from the top. We will use the bottom section without the colored bottom cup. Use a bottle that will stand without a bottom cup.

2. Use clay to form a hill and any other landscape features you choose in the bottom of the bottle. You may choose to leave one area depressed as to simulate a pond or lake.

3. Make marks on the side of the container to indicate 1 centimeter increments from the bottom to the top.

4. Record the level of the land/clay in accordance with the marks on the side of the container. How many centimeters does your clay landscape rise from the bottom of the container?

5. Slowly pour water into the container and onto the clay landscape. Add water until it becomes level with the first centimeter mark from the bottom of the clay. Describe how much of the clay landscape is now covered with water.

6. Put two or three small marks on the rim of the bottle. These will correspond to marks that will be made on the transparent sheet to help keep its position constant.

Materials

(for each group of four students)

- 2-liter soft drink bottle
- small plastic house/hotel piece, as from a monopoly game (optional)
- lump of clay, enough to fill the bottom of the 2-liter bottle
- clear overhead transparency or plastic sheet
- metric ruler
- overhead transparency marker or grease pencil
- container for holding water

7. To construct a contour map, place a blank transparency on top of the container. Draw a circle on it to indicate where it touches the rim of the container, and mark your registry points from the rim as well.

8. Look straight down from above the bottle (not at an angle) and draw a line on the transparency where the water meets the clay (the shoreline).

9. Take off the transparency and add more water to the bottle until it is level with the second centimeter mark. Replace the transparency in exactly the same location (lining it up with the dots and rim circle). Draw another line on the transparency as in Step 8 to indicate the new water level.

10. Continue adding water a centimeter at a time and drawing the contour line (where the water meets the clay) until the clay is completely submerged.

11. The finished transparency can be traced onto a sheet of paper for future reference.

Interpreting the Model

After constructing your contour map, answer these questions.

A. How can contour maps be useful to geologists, farmer, marina owners, boaters, or others whose work is directly related to the coastal landscape?

B. If the water level decreased 1 centimeter in elevation on your model, how much more land was exposed? Figure out how you could determine this mathematically and defend your answer.

C. If a contour map has an area in which the contour lines are very close together, what does this indicate?

D. How are flat areas shown on a contour map?

E. Describe how a lower water level, such as what the Great Lakes will likely have with global change, has different effects on steep versus flat areas.

Answers

A. Show the lay of the land and how steep the offshore parts may be.

B. A reasonable approach would include use of a transparent grid, counting the number of squares between contour lines.

C. It indicates a steep slope. The land is changing elevation quickly, across a relatively short horizontal distance.

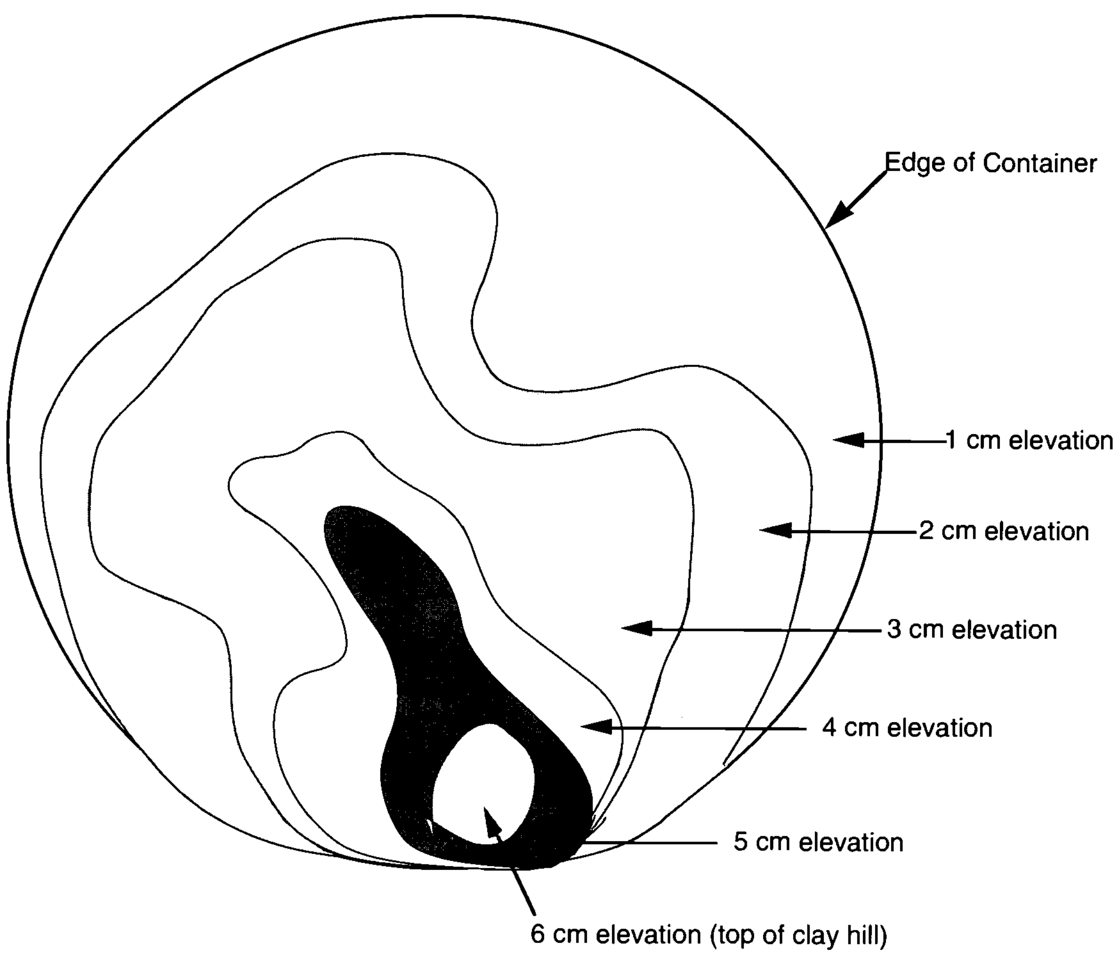
D. In flat areas the contour lines are far apart.

E. Lower water will expose much more new lake bottom in areas that are flat, shallow or have low slope.

EXTENSIONS

Drain off most of the water. Place a miniature house or hotel (possibly a small game piece) at some location you would consider "safe" from drastic changes in the water level of a lake. Describe the location you chose, and indicate it on your transparency contour map. A more complex terrain could be constructed in a larger container.

Sample of a contour map created by this method

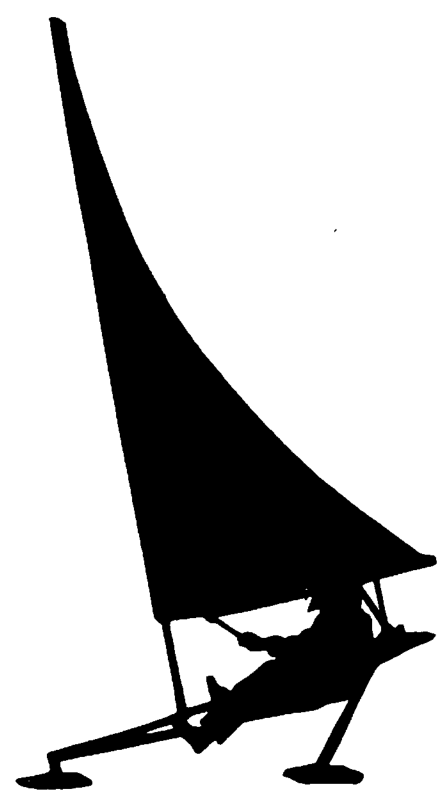


Recreation: Where Will We Play?

What do you think of when you hear the words "Great Lakes region"? Many people think of beautiful shorelines, shipping and cities such as Cleveland and Chicago. Another thought that comes to the minds of many people is recreation: boating, fishing, swimming, skiing, snowmobiling, hiking, camping, hunting, and birding.

The economy of the Great Lakes region depends heavily on travel and tourism; therefore, any factor that affects recreation in the area could potentially affect the economy there. If global warming occurs, the Great Lakes region will undergo longer summers and shorter winters. Water temperatures are expected to increase up to 5° C, the amount of snow would decrease, and lake levels would drop (up to 3 meters). The impacts of these changes could shape the future of recreation in the Great Lakes. The health of the recreation industry, in turn, affects the region in other ways, including:

- *Economic Growth*. Tourist dollars create jobs and bring in new businesses.
- *Amenities*. Hotels are not just for tourists. They bring in conferences and meetings.
- *Social Impacts*. Tourism brings diversity, in people and ideas, to an area. Also, popular tourist areas often encourage second homes — thus helping the local economy.
- *Preservation*. Well–planned and organized tourism can aid in the preservation of local historic and natural attractions.



The above-listed effects are positive ones. Tourism, however, can also have negative effects:

- *Change*. Tourism brings in new people and demands. If the changes take place too quickly and development gets out of control, an area can quickly become a "tourist trap."
- *Environmental Degradation*. Like any development activity, tourism can lead to pollution and destruction of local ecosystems.
- *Crowding*. Congestion and destruction to the infrastructure can result from increased human density and activity.

This set of activities considers present recreational activities in the region and how they might be affected by climate change.

Activity A: How might global warming affect recreation around the Great Lakes?

Maintaining a healthy, well–organized and well–planned recreation industry is vital to the Great Lakes. Knowing that recreation has such wide–reaching effects in the region, it is important to understand what affects recreation. Conditions that can either foster or inhibit recreation include:

- Geographic characteristics
- Demographics
- Economics
- Environmental quality

Earth System Understandings

This activity focuses on ESU #1 (aesthetics and value), #2 (stewardship), #4 (interactions) and #7 (careers and hobbies). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#8, What could happen to Great Lakes recreation?

Materials

- Before beginning this activity, collect recreation and travel information from your Department of Natural Resources, automobile clubs, visitor bureaus and travel agents. A list of potential sources appears at the end of this activity.
- Transparent copies of the outline maps of the individual Great Lakes (two identical ones per team)

Answers

2. Answers will vary by lake. For each popular activity, students should be able to tell if it depends on geography (some special natural feature), demographics (close to population centers or popular with all ages), economics (not too expensive for anyone to enjoy, or not too expensive to develop) and environmental quality (good, clean places for the activity). Those less popular may be too expensive, too far away, infrequently available, or other variation of the conditions.

Objectives

Students who have completed this activity should be able to:

- Discuss the implications of global warming for recreation in the Great Lakes region.
- Identify and debate possible ways that recreation managers can deal with the global warming challenge.

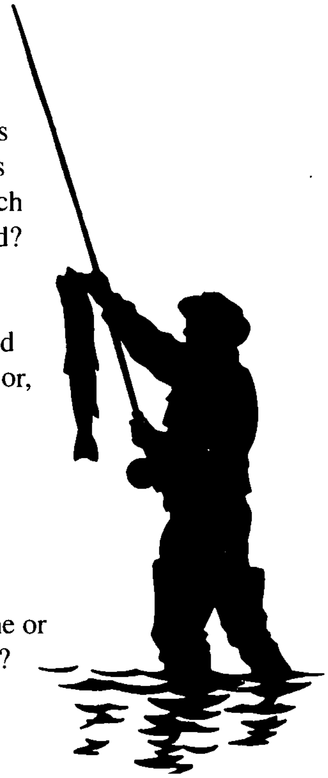
Procedure

Prelab: Have students read the recreation scenario #8 before they begin the activity. Make transparencies of the provided Great Lakes outline map for the lake nearest you, or for all lakes (see #1 below).

1. Divide the class into groups for study of the nearest Great Lake and its recreation facilities. Alternatively, assign each group of students a different Great Lake and allow time for comparison.

2. Review maps and travel brochures from your Great Lake. What seem to be the three most popular recreation activities in the region? How do they depend on the four conditions above? How do other (less popular) activities differ on these conditions?

3. If global warming occurs, the temperature of the region's lakes is expected to rise and water levels are expected to fall. Of the species of fish currently in your lake, which ones would most likely be affected? If they live in Lake Ontario, could they migrate and escape the problems? Where would they need to go? If they lived in Lake Superior, could they migrate? Where would they go? In what ways would a change in your local fish species affect the fishing industry?



4. What other Great Lakes recreation activities would be likely to decline or move to another part of the region? Which ones would expand?

5. On one transparency, students in a group should indicate the location of major recreation areas and businesses as they exist today. Construct a key so that all groups use similar symbols to stand for recreation types. For example, use a snowflake to designate a ski area. On a second transparency, groups indicate the location and types of recreation as they project they will exist 50 years from now.

6. For one of the recreation types, list the types of jobs within the industry and supported by it. Ask participants in the recreation if your list is complete, and add other jobs they suggest. Then determine if those jobs are flexible enough to change if climate changes. How much demographic and social change would you expect if the recreation type changes?

7. Pretend that your group represents a consulting organization, hired to suggest to a panel of Great Lakes recreation managers ways that they can prepare and adjust for global warming. What businesses would you recommend to expand their operations? Which ones would you advise to either relocate or change their focus? What are your predictions overall for the health of the recreation industry in the Great Lakes region?

3. Answers will vary by lake. Typically, fish requiring cold water to live in, or shallow waters to spawn, may be affected by loss of those habitats. To escape temperature problems in the lakes, fish could go to colder waters, but in Lake Ontario they can't go upstream because of Niagara Falls. They can't go far downstream because the waters eventually become brackish (salty) in the St. Lawrence River. They would have to go up rivers, but waters there would be low. In Lake Superior, upstream means up the rivers, and downstream would not solve the problems. In all cases the fishing industry could lose valuable species from the lakes where they were accustomed. If the fishers could not shift to new species because of customer preference or different types of gear needed, they would go out of business. To find temperature preferences of fish, consult the Activity "How will global warming affect Great Lakes Fish" in this book. Natural history guides and experienced anglers would also be useful resources.

4. Decline or a move could be predicted for the cold weather / cold water recreation forms — skiing, ice fishing, ice boating and the like. Expansion of warm weather / warm water recreation is in order: water sports, camping, etc., although new access to water would have to be developed at its lowered levels. Students will have other ideas based on their own experiences. Many answers are acceptable.

5. Be sure students include state, provincial and national parks, resorts, amusement parks, and a wide range of other recreation forms.

6. For example, sport fishing supports manufacture of fishing gear, sales of the gear, sales of auxiliary equipment like tackle boxes and personal flotation devices, bait production and sales, boat sales and service, gasoline sales, food and beverages for fishing trips, motels and campgrounds staffing and maintenance, charter boat booking, captain services, fish cleaning, etc. Some of these jobs are flexible because they serve others besides fishers (check the flexible ones!). There could be significant changes in lakeside communities that serve the sport fishing public. Students should be able to imagine many differences.

Teacher's Note

Students should think broadly about what constitutes outdoor recreation. Remember to include the following types, and add local pursuits as well.

boating
swimming
camping
gardening
water skiing
snow skiing
ice fishing
bungi jumping
parasailing
team games (baseball, hockey etc.)
indiv. games (goal, tennis, etc.)
birdlife & birdwatching
racing (cars, horses, etc.)
landscape painting
sky or water diving
fishing
hiking
biking
hunting
jogging
running
sightseeing
nature crafts
jet skiing

Review Questions

1. In general, what types of recreation are likely to be affected by global climate change? Will effects be positive or negative?

2. Recommend ways the recreation industry could prepare to accommodate or adapt to the changing climate.

Extensions

Activity B will give students an idea of the decision making process that will face the recreation industry as it prepares for the future.

Sources of Recreation Information

Illinois
Department of Energy and Natural Resources
325 W. Adams St., Rm. 300
Springfield, IL 62704-1892

Michigan
Department of Natural Resources
Box 30028
Lansing, MI 48909

New York
Department of Environmental Conservation
50 Wolf Rd.
Albany, NY 12233

Ohio
Department of Natural Resources
Fountain Square
Columbus, OH 43224

Ontario
Ministry of Natural Resources
Toronto, Canada M7A 1W3

Indiana
Department of Natural Resources
402 W. Washington St., Rm. C256
Indianapolis, IN 46204-2212

Minnesota
Department of Natural Resources
500 Lafayette Rd.
St. Paul, MN 55155-4001

Pennsylvania
Department of Environmental Resources
Public Liaison Office
PO Box 2063
Harrisburg, PA 17120

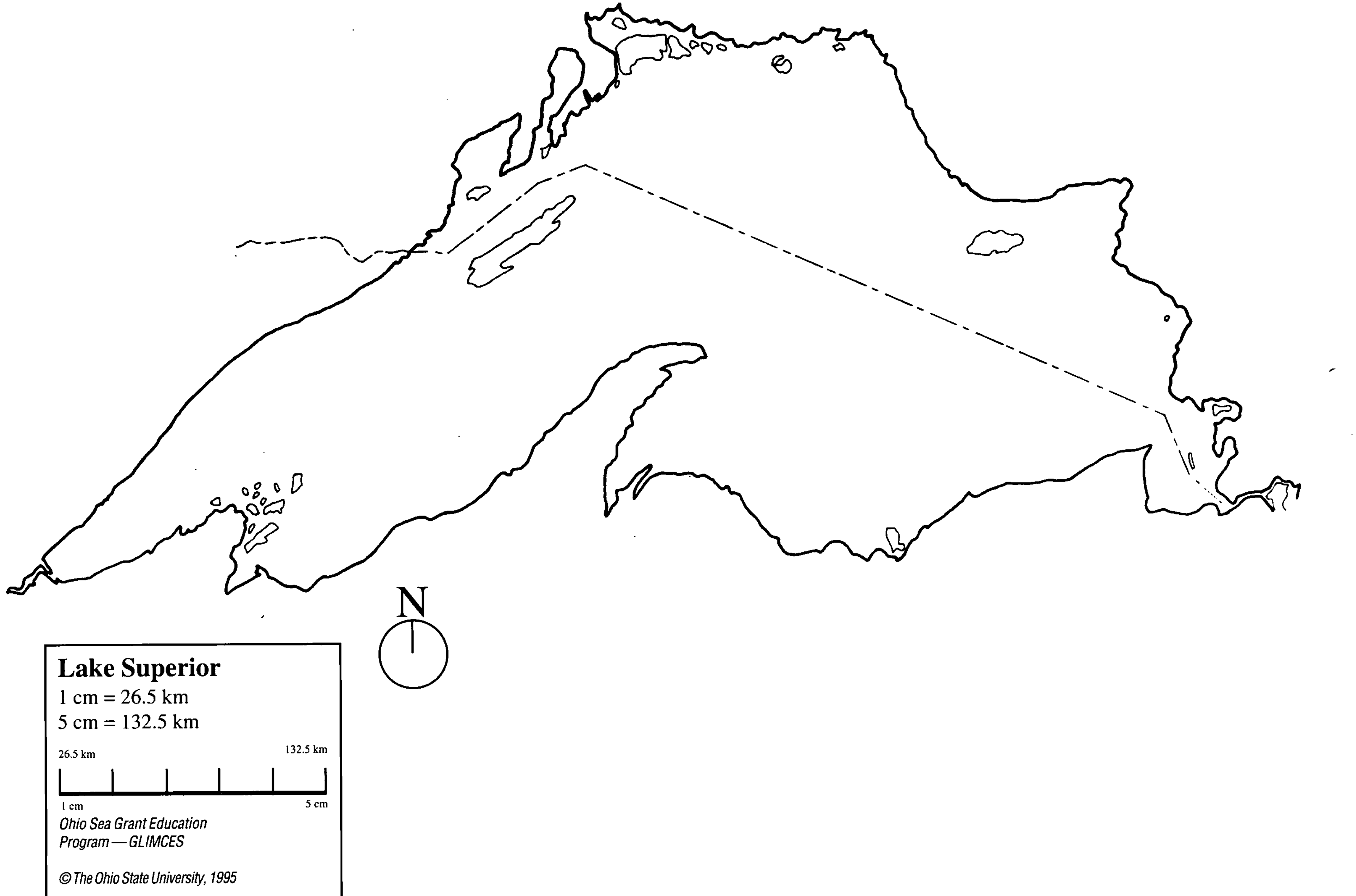
Wisconsin
Department of Natural Resources
PO Box 7921
Madison, WI 53707

Other References

Cantor, George. 1980. *The Great Lakes Guidebook: Lake Superior and Western Lake Michigan,* Ann Arbor, MI: University of Michigan Press.

Cantor, George. 1985. *The Great Lakes Guidebook: Lake Huron and Eastern Lake Michigan*, Ann Arbor, MI: University of Michigan Press.

Cantor, George. 1985. *The Great Lakes Guidebook: Lake Ontario and Erie*, Ann Arbor, MI: University of Michigan Press.


N
Lake Superior
1 cm = 26.5 km
5 cm = 132.5 km
26.5 km
132.5 km
1 cm
5 cm
Ohio Sea Grant Education
Program — GLIMCES
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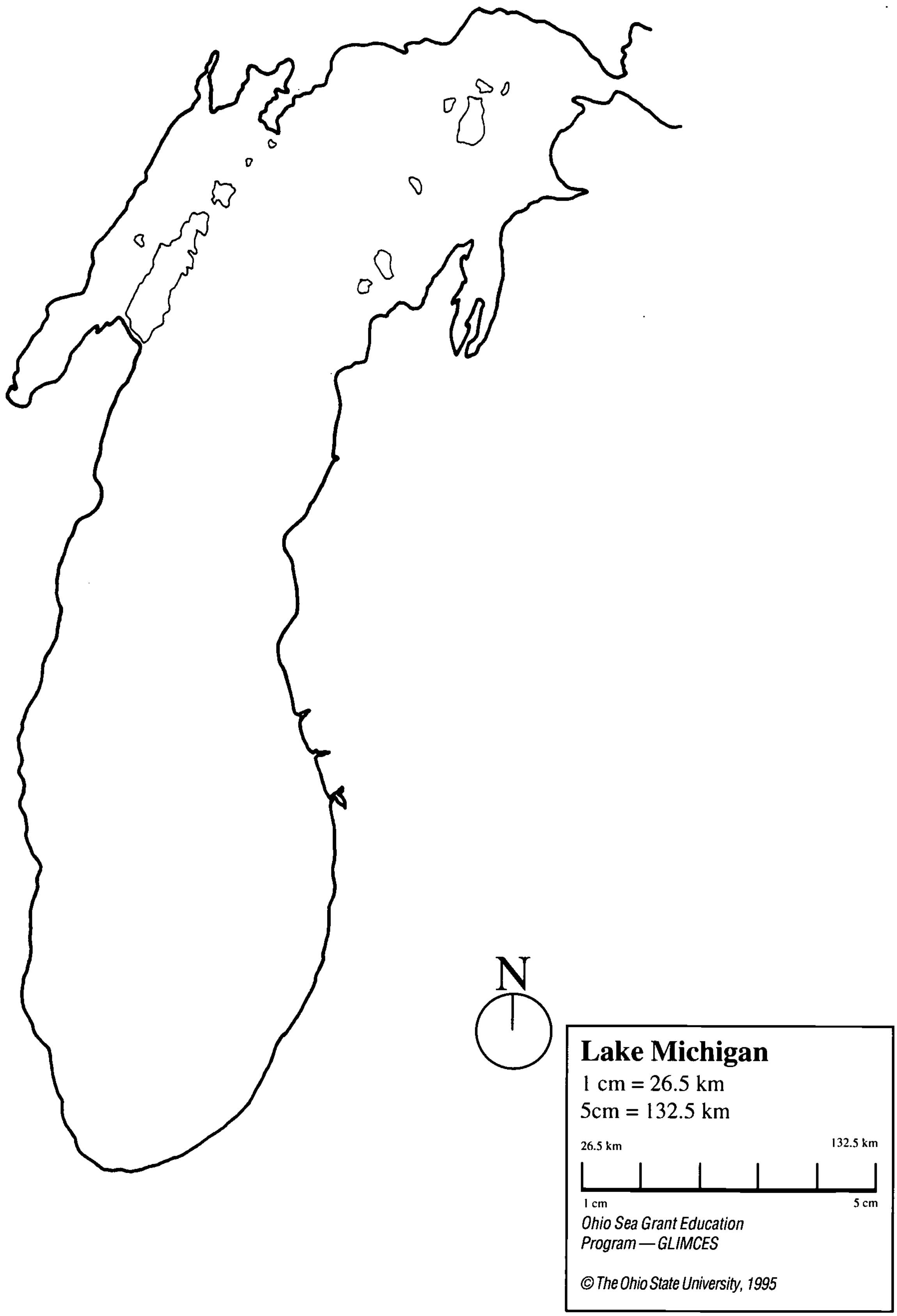
N
Lake Michigan
1 cm = 26.5 km
5cm = 132.5 km
26.5 km
132.5 km
1 cm
5 cm
Ohio Sea Grant Education Program — GLIMCES
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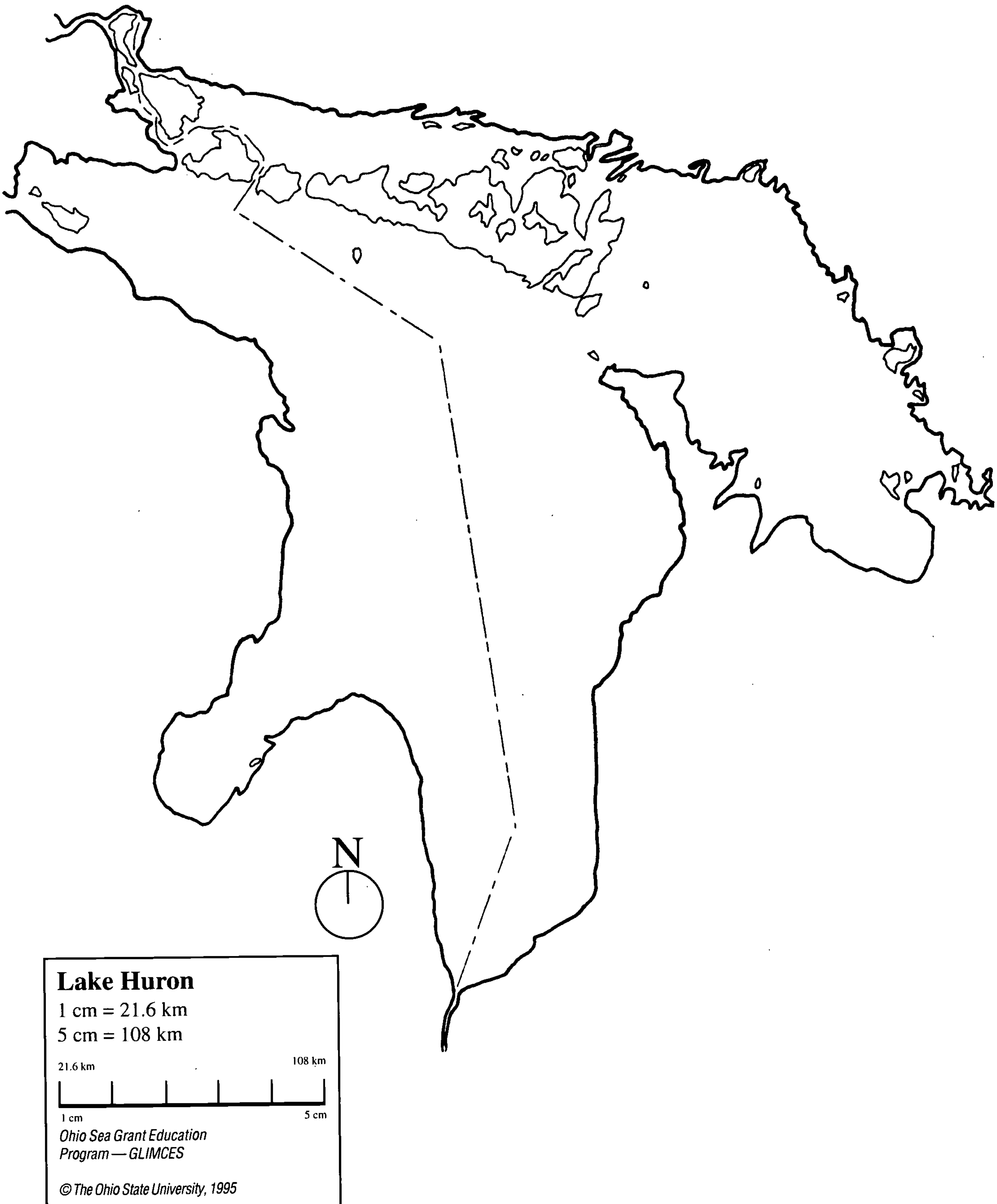
N
Lake Huron
1 cm = 21.6 km
5 cm = 108 km
21.6 km
108 km
1 cm
5 cm
Ohio Sea Grant Education
Program — GLIMCES
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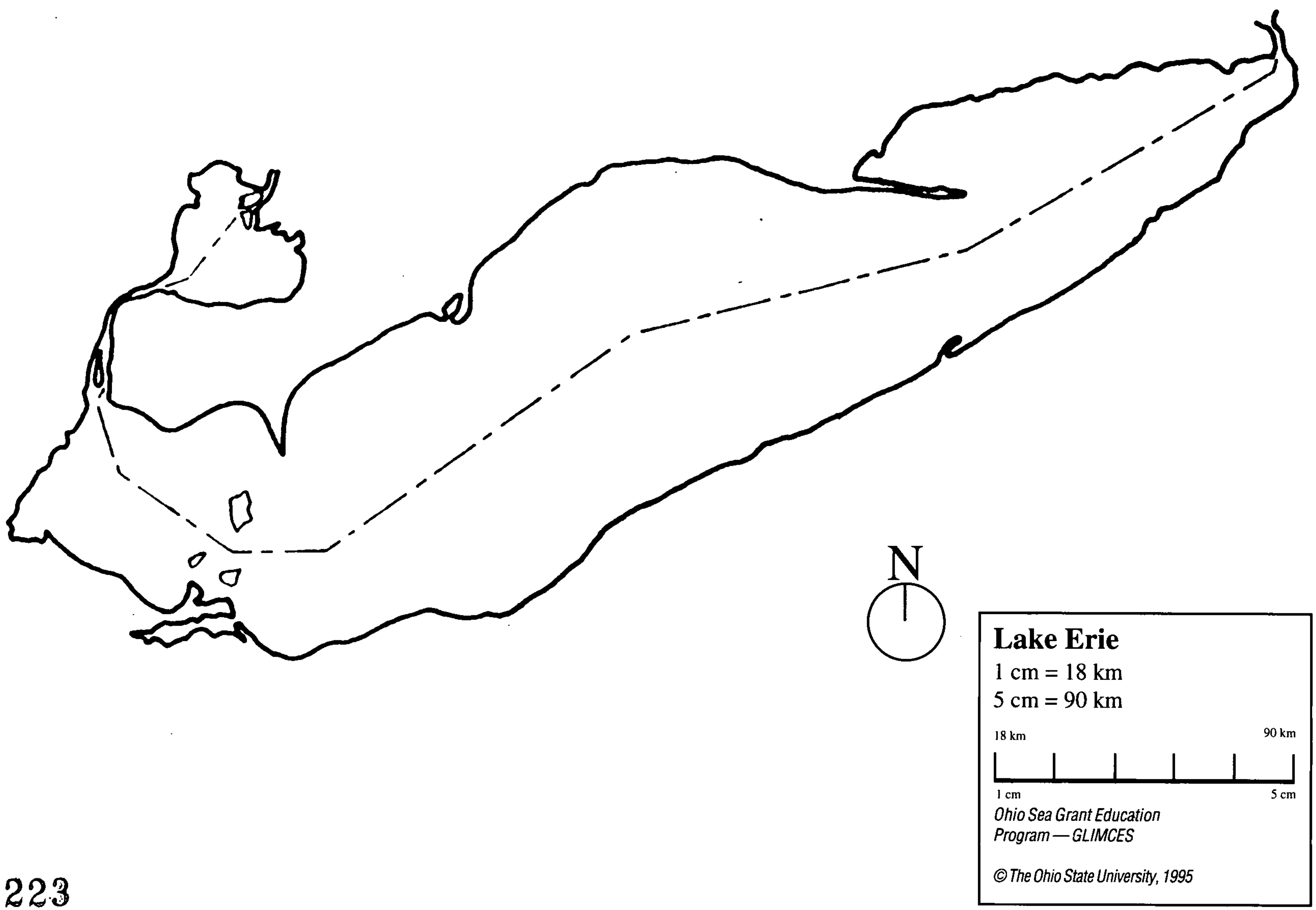
N
Lake Erie
1 cm = 18 km
5 cm = 90 km
18 km
90 km
1 cm
5 cm
Ohio Sea Grant Education
Program — GLIMCES
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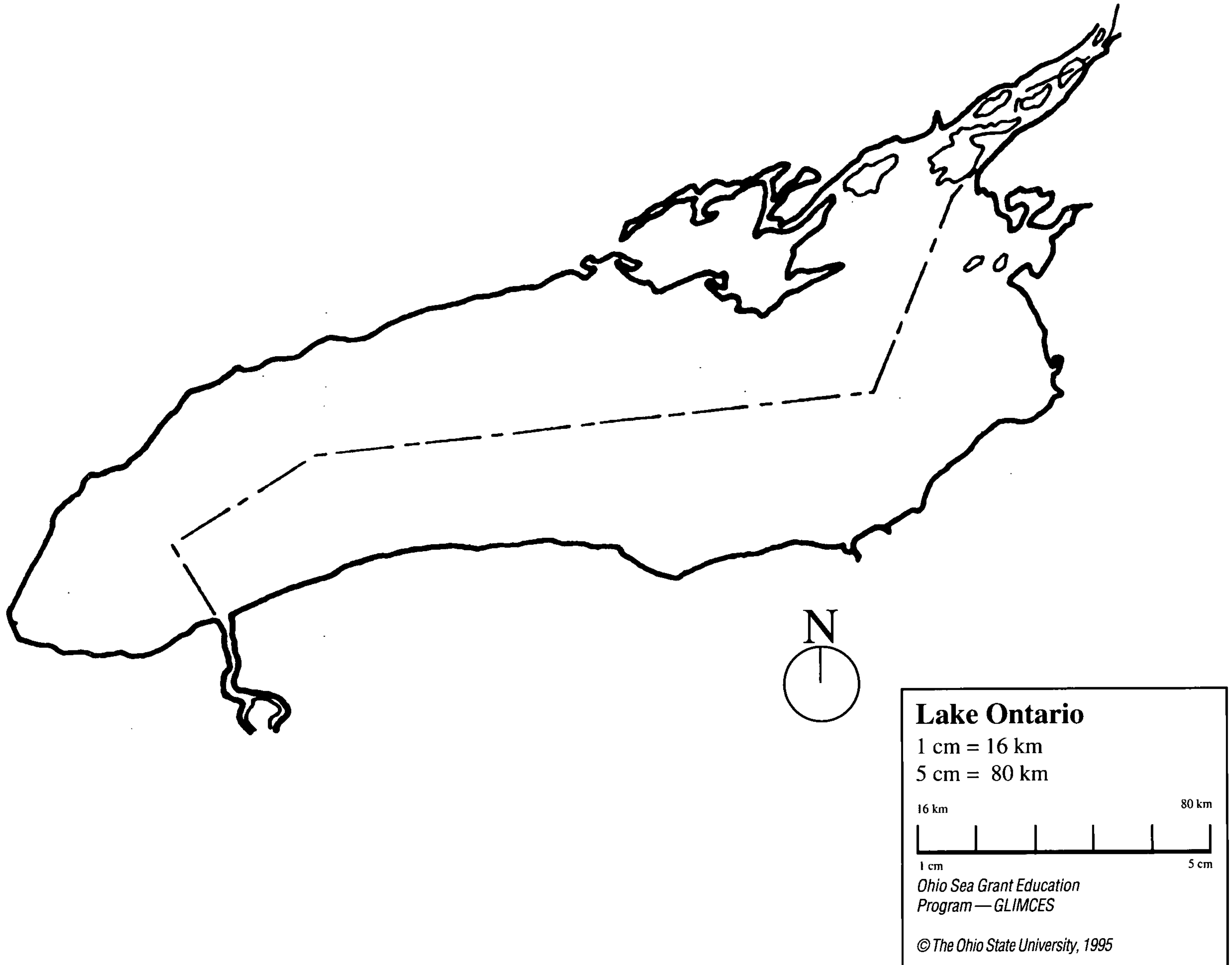

N
Lake Ontario
1 cm = 16 km
5 cm = 80 km
16 km
80 km
1 cm
5 cm
Ohio Sea Grant Education
Program — GLIMCES

Activity B: Should we develop winter or summer recreation?

Climate change, if it occurs, will very likely shape the Great Lakes environment in such a way as to impact the recreation industry. Increased temperatures could result in increased rainfall, but also an increase in evaporation rates that would result in a net loss of water in the region. Water levels would lower, with several important implications for the region's recreation industry:

- Adjacent marshes and swamps in the region could dry up if lake levels drop, affecting bird and fish breeding sites. Recreational activities associated with wetlands, such as hunting, fishing and birdwatching would suffer.
- Receding water levels could potentially move shorelines, affecting hiking trails, campsites and other areas whose uses are enhanced by proximity to the water.
- Boating would suffer if water levels are lowered. Channels would have to be dredged to allow boats access to docks.
- Concentrations of pollutants would increase if water volumes decrease. Water quality would then become a greater concern.

Resource managers need to anticipate possible changes in the travel industry. However, facts, not theory, are needed before potentially expensive changes are made. If global change accompanied by longer summers occurs, larger numbers of people may vacation in the region. Along with economic benefits, they would bring with them problems such as in increased potential for impact to the region's ecology. Planning needs to be done now to both accommodate them and moderate their impacts.

Earth Systems Understandings

This activity focuses on ESU #1 (aesthetics and value), #2 (stewardship), #4 (interactions) and #7 (careers and hobbies). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#8, What could happen to Great Lakes recreation?

Materials

- role–playing name cards and descriptions for each participant
- props optional for role play
- background information and resource materials for use in preparing presentation.

OBJECTIVES

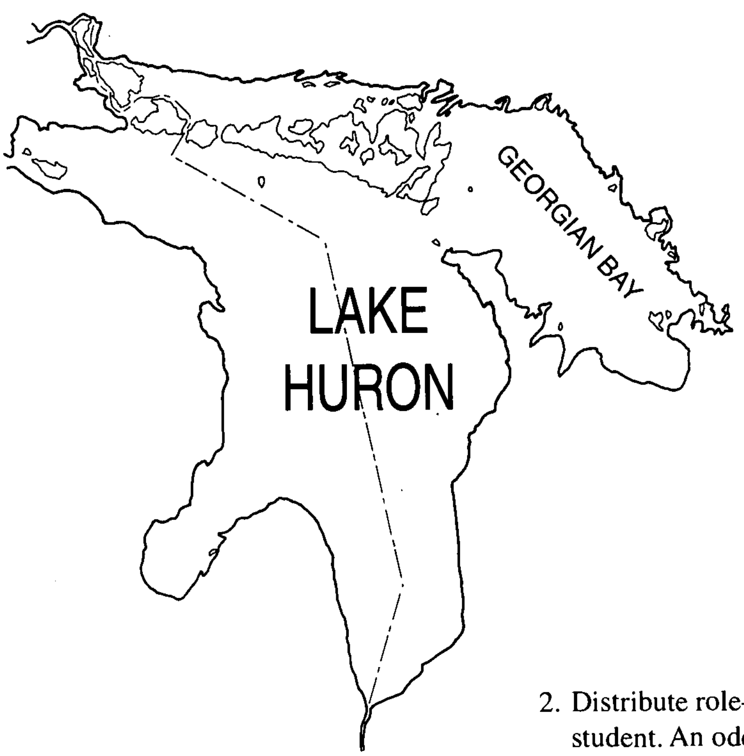
When students complete this activity, they should be able to:

- Realize that an environmental issue can be viewed from more than one perspective.
- Evaluate potential changes in recreational opportunities in the region.
- Describe the possible influence of global warming on the economy.

PROCEDURE

This role–playing activity demonstrates differing views about global climate change and the effect on recreation in the Georgian Bay area. Some people claim that global warming will occur, causing the climate in the Bay area to change, therefore influencing recreation. Others disagree with this viewpoint and argue that global warming will not occur and therefore not affect the climate and recreation in the region.

1. Establish the situation: the Georgian Bay Development Company is at a crossroads in light of the possibility of global warming. As it considers the future, the Board of Directors will decide whether to build a summer or a winter resort. Provide students with background information about the values of the recreation industry and the potential changes expected with global warming. (See Scenario and Introduction to "Where will we play?")



Location of Georgian Bay, a section of Lake Huron. Longitude range is 80-84° W and latitude is 44-46° N. The Bay freezes over in winter with current climate conditions.

2. Distribute role–playing name cards and descriptions to every student. An odd number of students should be chosen as Board members. There should be an equal number of students designated for both points of view. The remainder should have roles which could choose either point of view (community members). The names suggested can be altered to match the gender of the role players assigned.

3. Have students form groups according to their point of view to plan the strategy for their presentation. Allow time for students to find information and props to prepare for their roles.

4. Arrange the classroom to represent a meeting room at the Georgian Bay Development Company.

5. On the day of the meeting, students role play their positions and make presentations to the Board of Directors. After the presentations, the Board of Directors makes a decision based on the information presented, and states the rationale for its decision.

6. Following the decision, have a class discussion to summarize the issues that emerged during the presentations and the implications of the Board's decision.

Sample Role Play Descriptions:

*Board of Directors:	*Pat O'Million*, CEO *Char Mann,* Chairman of the Board *Dennis Wexler*, Company President
*Summer Resort Supporters:	*Bill Par*, local golf pro *Shawn Snorkel*, owner of scuba diving business *Jo Fisher*, owner of fishing equipment manufacturing company *Mark Airmass*, meteorologist who believes global warming is in progress
*Winter Resort Supporters:	*Tony Toboggan*, winter sports enthusiast *Adrienne Rink*, professional skater and owner of ice rink *Chris Breezy*, meteorologist who debunks global warming ideas *Frances Towrope*, owns controlling interest in ski equipment company
*Other Community Members:	*Sandy Realtor*, local real estate agent *Reggie Racer*, owns new & used car sales company *Terry Woodwork*, owns a large construction company *Cam Tabletop*, owns local restaurant

Review Questions

1. It has been said that global climate change will have both winners and losers. Discuss how recreation facilities and surrounding communities might view the changes from other perspectives.

2. Would you vote to build a winter or summer resort in the Georgian Bay area? Make a list of important factors to consider, and rank them from most to least important.

Evaluation

As members of the tourism industry, develop promotional materials for recreational opportunities in the Georgian Bay region as they might appear in the year 2055.

Extensions

1. Repeat the role play, but choose a different Board of Directors and exchange students' roles so that they have to argue from the opposite point of view.

2. Investigate the influence of global climate change on the climate, and physical and ecological characteristics of Georgian Bay. Determine if and how the shoreline would be altered and how existing recreation opportunities in the Georgian Bay might be impacted. Debate, with another meeting, where to build a summer resort in the Bay region and what types of recreation should be included at this resort.

3. List recreational opportunities in your local community and determine what impact global climate change could have on these.

References

Firor, John. 1990. *The Changing Atmosphere: A Global Challenge.* New Haven: Yale University Press.

Great Lakes Commission. 1989. *Travel Tourism and Outdoor Recreation in the Great Lakes States: A statistical profile.* Ann Arbor, MI.

Revkin, Andrew. 1992. *Global Warming: Understanding the Forecast.* New York: Abbeville Press.

Wall, Geoffrey. 1988. Implications for climate change for tourism and recreation in Ontario. *Climate Change Digest* Downsview, ON: Canadian Climate Centre. CCD 88-05.

Environmental Response

Activity A: What should people do about global change in the Great Lakes?

There are three possible responses to global change. People can *abate* the situation (stop the changes from happening), they can *adapt* to the changes, or they can *accept* them and do nothing. The option chosen depends on many factors. In 1986, researchers at Southern Illinois University pulled together all the existing studies on responsible environmental behavior. They developed the model below to show how the factors influencing this behavior might fit together (see Figure 1). The model isn't perfect, but it does remind us of some things that might encourage people to be environmentally responsible. For instance, if people learn about a problem, and are shown some things they can do to help solve it, they will be less likely to feel helpless and do nothing.

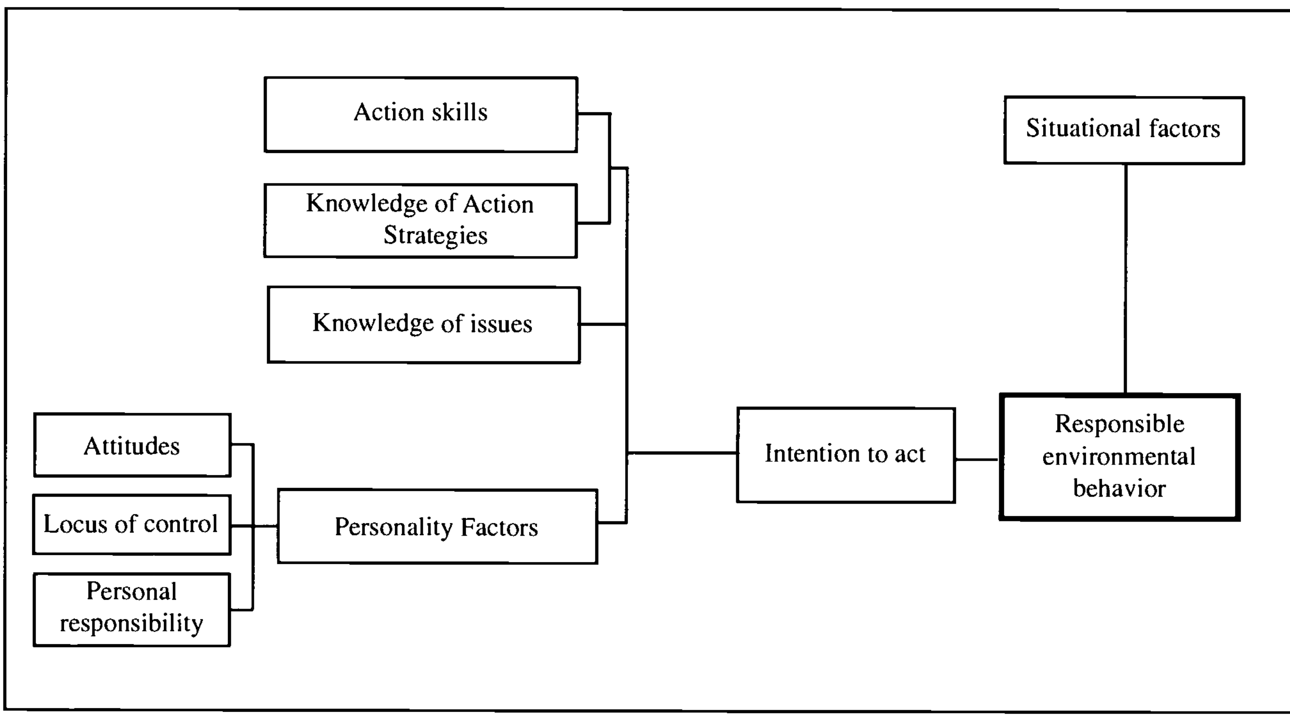
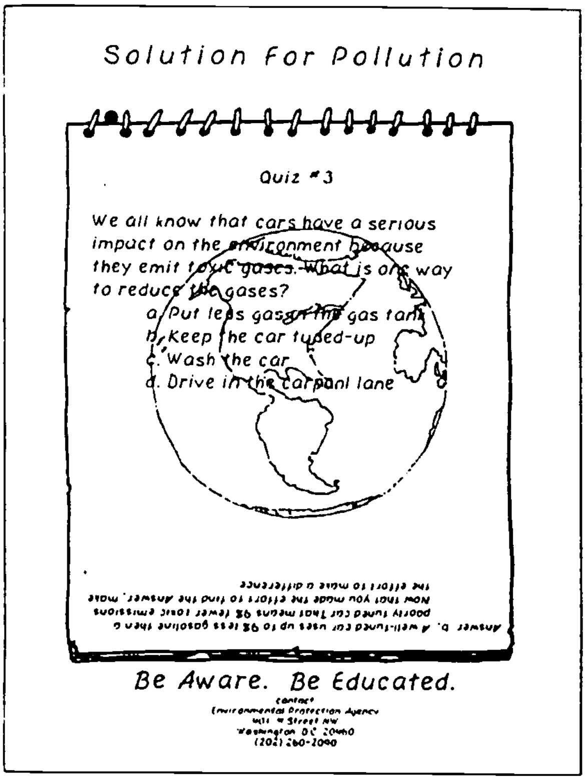
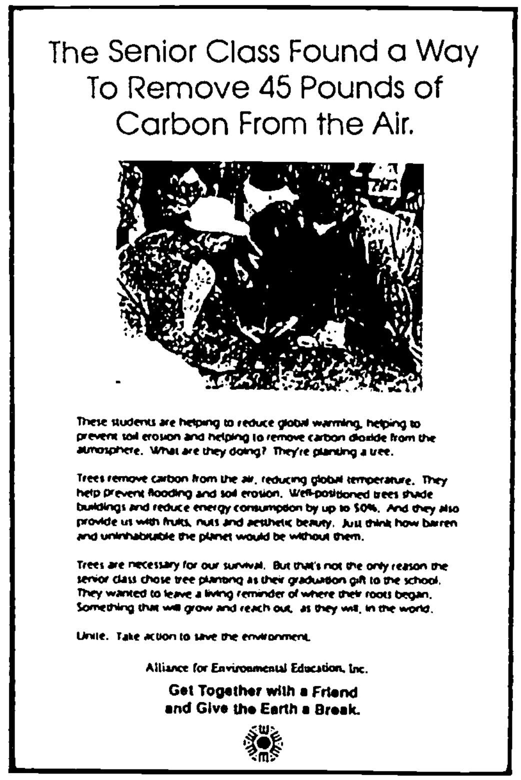


Figure 1. The Hines Model of Responsible Environmental Behavior (1986/87)

One way people learn about topics they can act upon is through advertising! Advertisers want people to know about the value of vitamins, biodegradable bags for lawn clippings, etc., and they want to sell people products that will enable them to act on their new knowledge. Of course, whether people act on their knowledge will depend on situational factors such as ready cash, availability of the product and other things. Advertisers try to overcome as many barriers to action (buying) as they can by preparing very appealing ads.

In 1991–92, the American Academy of Advertising and the INAME Foundation sponsored a student competition for ads relating to the environment. Samples of their winning entries are shown here:





Earth System Understanding

This could involve any of the understandings depending on the subject matter chosen. Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

Varies by choice of subject.

OBJECTIVES

After successfully completing this activity you will be able to:

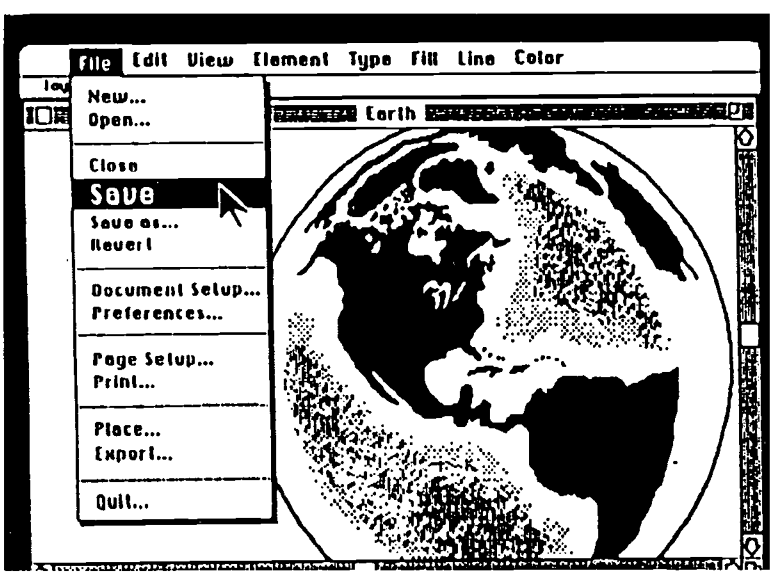
- Give examples of behavior that can accept, adapt to or abate global change.
- Use advertising to make people aware of things they can do about global change.

PROCEDURE

1. Decide what you or your team want people to know and do about global change in the Great Lakes. List ideas. You may want them to conserve water because there will be less to spare. You may want them to switch from fossil fuels to alternative energy sources. You may just want to encourage them to wear hats and sunglasses.
2. Decide whether these responses are examples of acceptance, adaptation or abatement. Which category of response is easiest for students to act upon? For parents?
3. Use the word processor and art supplies to develop a one–page ad to convince people to perform an environmentally conscious behavior.
4. Make a display or booklet using your ads. Offer some to local news media.

Materials

For this activity you will need:
- marking pens
- paper
- photos or line art
- word processor (optional)



Save . . .
When you're putting that extra little something into your savings account, what are you thinking about? A new car? A new home? That vacation you've always wanted? Did you ever think you might not be around to spend it? Or your family be around to spend it? Or anyone around at all? Did you ever think, during all your work and running around, about the most important thing concerning you? Your world: the air you breathe, the water you drink, and the ground you stand on. Is it safe? If you don't know, find out. Call your local and state governments to learn your part in environmental safety. Pollution control is at your command.

Alliance for Environmental Education

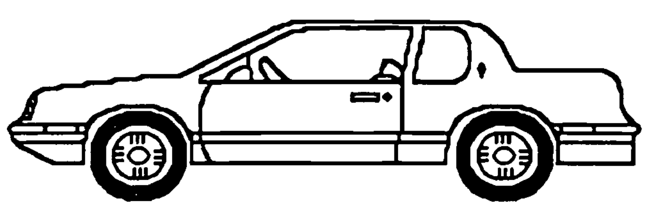
Activity B: How do energy use decisions influence global change? (Cars on Trial)

This activity encourages discussion about energy use decisions, greenhouse gases, and global warming. In it, a trial is held in which automobiles are accused of emitting a dangerous gas (carbon dioxide) into the atmosphere. The students (jury) must decide how harmful they think automobiles really are and what, if anything, should be done about them.

Carbon dioxide is a greenhouse gas. When it accumulates in the atmosphere it traps heat from the sun, warming our biosphere like the glass of a greenhouse traps heat in the enclosed space. The Earth's atmosphere is largely composed of nitrogen and oxygen. These molecules are transparent to visible light and infrared radiation while they absorb some ultraviolet wavelengths. Greenhouse gases (carbon dioxide, nitrous oxide, ozone, water vapor, and methane) each absorb infrared radiation (heat). If the Earth's atmosphere only contained nitrogen and oxygen the surface air temperatures would be about negative 18°C. However, the world has a mean surface air temperature of about 15°C because of the presence of the greenhouse gases in the atmosphere. These gases act as a blanket, keeping us warm, just as ozone acts as a shield in the stratosphere, protecting us from ultraviolet rays.

The burning of fossil fuels, such as gasoline, releases carbon dioxide into the atmosphere. Some interesting statements concerning gasoline, cars and CO_2 emissions include the following. These facts and additional information can be found in the 1991-92 *Green Index*, Worldwatch Institute Papers 98 and 100, and the 1994 *World Almanac.*

- The U.S. contains about 5 percent of the world's population and owns a third of the world's cars. Americans drive as many miles as the rest of the world combined.
- American cars and trucks cover more than two trillion miles a year, the equivalent to a trip to Pluto and back every day.
- In France and Italy, the average driver gets 34 miles per gallon of gas, while U.S. drivers average 18 miles to a gallon.
- Passenger cars account for more than 13 percent of the total carbon dioxide emitted from fossil fuels worldwide, or more than 700 million tons of carbon dioxide annually.
- In the U.S., where fewer than 10 percent of employees pay for parking, employers can deduct the expense of providing parking from their taxes.
- Of the top 50 U.S. industrial exporters listed in the 1994 *World Almanac*, General Motors is number 2, Ford is number 5 and Chrysler number 6.
- Oil use as of 1990 averaged 4.5 barrels per person worldwide, with the U.S. at 24 barrels per person.
- The U.S. government subsidizes oil. If we paid the full price of extracting, importing, refining, and cleaning up after oil, the cost would probably exceed $4.00 a gallon.



Objectives

Students will:

- Be able to list several pros and cons regarding the use of automobiles in America (or Canada).
- Think critically about the complexity of reducing the amount that Americans (or Canadians) drive cars.
- Understand the basic effect of CO_2 in the atmosphere.

Procedure

1. Decide who will play which role. Students without specific roles will be part of the jury.

2. Give lawyers and witnesses their cards and some time to prepare for their role (preferably overnight). They should be made aware of courtroom procedures. The lawyers should also read all of the witness cards prior to the trial and will want to talk to their respective witnesses regarding the questions they will ask. The witnesses for the prosecution are the air and the CO_2 expert. The witnesses for the defense are the car and the teenager.

Courtroom Procedure

4. The bailiff announces the judge: "All rise, the Honorable Judge . . . is presiding"

5. The judge enters, calls the court to order and introduces the case with the following statement: "Today, all of the cars in this nation are on trial. They are accused of emitting harmful CO_2 into the atmosphere, causing global warming."

6. The judge then introduces the defense and prosecuting lawyers who give their opening statements.

7. Prosecution calls its first witness (the CO_2 expert) to the stand for questions. Following this the defense lawyer may cross examine the witness.

8. The prosecution then gets to call a second witness (the air). Again the defense may cross examine.

9. Next, the defense may call its first witness to the stand (teenage driver). The prosecution may cross examine.

10. Defense may then call their second witness (the car). The prosecution may cross examine.

Earth Systems Understandings

This activity focuses on ESUs #2 (stewardship), #3 (science methods and technology), and #7 (careers and hobbies). Refer to the introduction of this book for a full description of each understanding.

Scenario Reference

#5, Will it affect airborne circulation of toxins?

Materials

- any props useful for the trial, such as a gavel for the judge, professional clothes for the lawyers, etc.
- resource materials so that the lawyers and the witnesses can research global warming, carbon dioxide levels, the role of greenhouse gases, the use of automobiles in America, and other related topics.
- the prosecution may want to use other materials from this book, such as the chart of average world temperatures and the demonstration of how CO_2 traps heat with Activities A and C under Global Climate Change.

The cast includes

Bailiff:
Strong silent type

Judge:
The teacher is the ideal person for this role to help steer the discussions in productive ways as well as retaining order.

Prosecuting lawyer:
Opinion is that CO_2 is made by cars; therefore, cars are responsible for global warming.

Defense lawyer:
Opinion is that automobiles offer benefits to humanity overriding concerns about CO_2 and global warming.

Air: Prosecution witness

Car: Defense witness

CO_2 expert:
Prosecution witness

Teenager with license:
Defense witness

Scribe:
This person records the decision of the jury, and he or she should be a part of the jury.

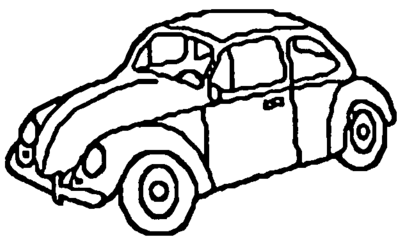
Jury (rest of the class):
Determines the verdict

11. After the lawyers and witnesses have finished, the judge asks the jury if there are any questions.

12. It is now time for the jury to decide the verdict (remedy). The judge should remind them that they must keep the good and safety of society in mind. Is the automobile a menace to society or a useful convenience?

13. Lawyers and witnesses may not interrupt or take part in this discussion. If a clarification of a particular detail is needed, questions may be asked by the jury to the appropriate party.

14. Have one member of the jury write up the conclusions of the jury. Once the jury has agreed on a conclusion, it should be read aloud to the entire courtroom.



Review Questions

1. What do the students think is an environmentally responsible way to use vehicles (keep in mind that we live on a planet where the population is constantly expanding).
2. Is it fashionable/popular/cool to use automobiles in an environmentally safe manner? Why or why not?
3. What factors are barriers to implementing the decision of the jury? How feasible would the jury's decision really be? How many people in the population would agree with the jury's decision?
4. What will happen if no action is taken and the automobile industry continues to grow and prosper while the price of gas remains affordable.
5. What do students predict will most realistically happen to the way Americans use cars?
6. There has been an increase over the past several years in the percentage of cars that are luxury cars. What would make it fashionable to drive an economical car?
7. Brainstorm which things society has at one time esteemed as being "the *in* things to do" but are generally thought of as in bad taste now because of environmental or health reasons?
8. On a worldwide level, the United States has significantly more emissions than developing countries. Some people believe that the goal of these countries is to attain the U.S. life-style. What should happen if they all did? What would we recommend to them.
9. Is a more affluent life-style always better? What sorts of life-styles do the students hope to create for themselves some day? Would any students prefer a house or car that is not luxurious over one that is? What is ideal?

Answers/Ideas for Review Questions

1. Ideas should spark discussion. Entertain all ideas equitably.
2. Answers will depend on the decision of the jury, economics of the car industry, status of owning and driving certain kinds of cars, lack of alternative methods of transportation, reasonable price of gas, etc.
3. Students should think of how population size, geography, political climate, need for transportation of goods, and other factors would affect the decision. They should also incorporate the concept of limited supplies of fossil fuels.
4. Allow students to consider/predict the future with continued patterns of automobile use.
5. Students can consider a range of ideas.
6. Earth sense and saving resources might be considered cool, or become popular ways of thinking.
7. These things might include wearing real fur coats, smoking, and tanning.
8. Students could create ways of pursuing economic development that are different than what has been done before. Countries could follow a different path.
9. The class could take a few minutes to draw an inventory of "their future home and property," and share their ideas with each other.

Character Cards

Judge

The role of the judge is to keep the trial running smoothly and to keep order in the courtroom. The judge may stand at a podium with the courtroom procedures in front of him or her to make sure they are followed. The judge has the ability to make the trial as humorous or as serious as desired.

Prosecution Lawyer

It is your job to make sure that the jury understands the serious negative consequences of carbon dioxide emissions, especially at its present rates which are constantly increasing. Your argument is that cars are polluting our air and having serious negative global effects. You think that society must concern itself with this problem soon before more serious damage is done, especially with the ever growing world population. Feel free to state statistics regarding the environmental harm that cars cause in order to impress that point upon the jury. Your opening statement should include the main points that you hope to prove during the trial. You must be ready with good questions to ask of the witnesses.

Defense Lawyer

Your job is to help the jury see how important and beneficial cars are to our society. Your opening statement should include the main points that you hope to prove during the trial. Some arguments you may want to incorporate into your defense are the following: (think up your own also).

- You may question the assertion that CO_2 is actually harmful in the atmosphere by claiming that the scientists have greatly exaggerated the consequences of CO_2 emissions in order to scare the public. You also are aware that scientists disagree on the subject of global warming. You want to know how the scientists who argue for global climate change got their data. Claim that no decision should be made until the data are verified and irrefutable.
- The economy of our society depends on cars. The automobile industry employs thousands of people: engineers, designers, mechanics, gas station attendants, factory workers, salespeople, advertisers, etc. We also export a significant number of cars.
- In America we greatly value our freedom to go where we want whenever we want without having to wait for a bus or travel with strangers. This depends on the ongoing use of personal vehicles.
- Ask the jury if they would want to wait for a bus or walk to the subway if any emergency happened. Cars can be lifesavers.
- American life would change dramatically without cars; they have become a symbol of the way we live. We are independent, free and have abundant resources.

Be ready with good questions for each of the witnesses when it is your turn to question them.

WITNESSES

CAR

You are on trial, and are being accused of emitting CO_2 into the atmosphere which causes global warming. You must answer any questions truthfully to the best of your ability but one argument you might make on your behalf is that you perform a useful function in society. You can bring up the point (feel free to interrupt the lawyers whenever you want to) that your only purpose on this planet is to serve the public, the very members of the jury, so you are amazed that these same people could be attacking you. You might remind them that you don't drive on icy roads and through potholes for your own good, but that you would rust yourself out driving people anywhere they wanted to go. Has the jury ever noticed how cars are treated in the movies — they're demolished. Remind them that if someone told you to drive over the cliff, you would do it as long as you're able, without even a question. The jury has a lot of nerve to blame you for causing them trouble. You may want to ask the jury how many of them hope to own a vehicle someday. Ask them how many of them rode in a vehicle today and how their parents would get to work without a car? Not only that, but you produce CO_2 which plants need in order to grow and produce oxygen. Feel free to really let the audience know how you feel.

CO_2 EXPERT

You have an extremely vital role in this trial. You represent the scientific community and present all (or most) of the actual data used this activity. Your job is to explain how CO_2 works as a greenhouse gas. You may want to do the demonstration located in Global Climate Change Activity C which shows how CO_2 holds in heat. (It takes some advance preparation.) You also need to describe the levels of CO_2 in the atmosphere and how they are steadily increasing. In this activity book is a chart of global temperatures (Global Climate Change Activity A). The defense lawyers may try to question your authority, so be sure of your facts! Bring in books and notes — you are the educated member in the court. You do not necessarily have an opinion about cars, you just present the facts as you know them.

DRIVING TEENAGER

Your job as a witness is to convince the jury that owning and using a car is a necessity in our society. For instance, you can talk about the job you have delivering pizzas and how you could not imagine doing it without your car. You don't think you could deliver pizzas by bus, subway or bicycle. You also work part-time on the weekends cleaning people's carpets — imagine carrying all those supplies and that equipment around on public transportation. You also go grocery shopping often for your family; without a car, you wonder how you would get 10 bags of groceries home. More importantly, you think that cars are fun. Driving is great; you can "blast" your music, you can take your friends wherever you want to go, like to the beach or the countryside, places off the beaten track. Your car is like your personality. Of course rush hour is bothersome and makes you nauseous but you think it would be a tragedy to loose any of the freedom that driving gives you.

AIR

You are vehemently against cars. You may want to claim that you are vital to the health of the planet. In fact, you keep the jury (and everyone else) alive from minute to minute, so they ought to be concerned with your health. You feel that automobiles are poisoning you. In some places of this country, people aren't supposed to go outside during times of the day because of the air pollution. You feel that drastic measures are needed to stop air pollution. You are retaining heat and think that this will have serious negative consequences. None of the jury can afford for things to become worse.

EXTENSIONS

1. Have students investigate the car that they ride in the most. What is its gas mileage? What will happen to it when it is time for it to be discarded? What happens to used oil after it is changed? Why was that particular car purchased? Was the environment one of the buyer's concerns?

2. How would people's life-styles change if society started using more public transportation or bicycling to work?

REFERENCES

Gates, D.M. 1993. *Climate Change and its Biological Consequences.* Sunderland, MA: Sinauer Associates.

For more information contact:
Worldwatch Institute, 1776 Massachusetts Ave. NW, Washington, D.C. 20036

Specific titles related to this activity include:
Flavin, Christopher, and Nicholas Lenssen. December 1990. Worldwatch Paper 100. *Beyond the Petroleum Age: Designing a Solar Economy.* Washington, D.C.: Worldwatch Institute.

Lowe, Marcia D. October 1990. Worldwatch Paper 98. *Alternatives to the Automobile: Transport for Livable Cities.* Washington, D.C.: Worldwatch Institute.

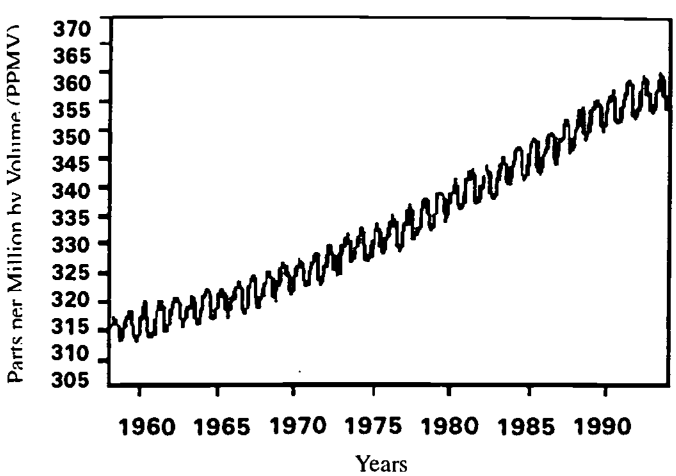


Figure 1. Monthly average CO_2 concentration, Mauna Loa Observatory, Hawaii

Reproduced from Reporting on Climate Change: Understanding the Science, *Environmental Health Center of the National Safety Council.*

Global Change in the Great Lakes Scenarios

The Ohio Sea Grant Education Program has produced a series of short publications designed to help people understand how global change may affect the Great Lakes region. By explaining the possible implications of global change for this region of the world, it is hoped that policy makers and individuals will be more inclined to make responsible decisions about global change policy issues. The scenarios describe the scientific community's prevailing interpretations of what may happen to the Great Lakes region in the face of global warming. The scenarios are written in terms the general public can understand, they include the most recent information available on a variety of subjects, and their content has been reviewed for accuracy by a panel of experts.

Introduction	Understanding Climate Models
Scenario #1	How Will Water Resources in the Great Lakes Region be Affected?
Scenario #2	Will Biological Diversity in the Great Lakes Region Suffer?
Scenario #3	What Could Happen to Great Lakes Shipping?
Scenario #4	How Will Agriculture in the Great Lakes Region be Affected?
Scenario #5	Will it Affect Airborne Circulation of Toxins?
Scenario #6	What are the Implications of Low Water Levels in Great Lakes Estuaries?
Scenario #7	Will it Speed Eutrophication in the Great Lakes?
Scenario #8	What Could Happen to Great Lakes Recreation?
Scenario #9	How Could Fish Populations in the Great Lakes be Affected?
Scenario #10	How Will Forests in the Great Lakes Region be Affected?

Additional Resources Available from The Ohio Sea Grant Education Program

Oceanic Education Activities for Great Lakes Schools (OEAGLS)

OEAGLS (pronounced "eagles") are designed to take a concept or idea from the existing school curriculum and develop it into an oceanic and Great Lakes context, using teaching approaches and materials appropriate for children in grades five through nine. Investigations are characterized by subject matter compatibility with existing curriculum topics, short activities lasting from one to three classes, minimal preparation time, minimal equipment needs, standard page size for easy duplication, student workbook plus teacher guide, suggested extension activities for further information or creative expression, teachability demonstrated by use in middle school classrooms; and content accuracy assured by critical reviewers. Each title consists of a student workbook and a teacher guide and costs $3.00 for the publication, postage, and handling. If ordering EP-026, add an additional $4.00 to cover the cost of the computer disk.

These publications are currently being revised and all titles may not be available.

The Effect of the Great Lakes on Temperature	(EP-001)
The Effect of The Great Lakes on Climate	(EP-002)
Ancient Shores of Lake Erie	(EP-003)
How to Protect a River	(EP-004)
Changing Lake Levels	(EP-005)
Erosion Along The Great Lakes	(EP-006)
Coastal Processes and Erosion	(EP-007)
Pollution in Lake Erie: An Introduction	(EP-008)
Yellow Perch in Lake Erie	(EP-009)
Evidence of Ancient Seas in Ohio	(EP-010)
To Harvest a Walleye	(EP-011)
Oil Spill!	(EP-012)
Shipping on The Great Lakes	(EP-013)
Geography of The Great Lakes	(EP-014)
Ohio Canals	(EP-015)
The Estuary: A Special Place	(EP-016)
The Great Lakes Triangle	(EP-017)
Knowing the Ropes	(EP-018)
Getting to Know Your Local Fish	(EP-019)
Shipping: The World Connection	(EP-020)
We have Met the Enemy	(EP-021)
It's Everyone's Sea: Or is it?	(EP-022)
PCBs in Fish: A Problem?	(EP-023)
A Great Lakes Vacation	(EP-024)
Storm Surges	(EP-025)
River Trek (with computer program)	(EP-026)
Waves	(EP-027)
Lake Layers: Stratification	(EP-028)
Nutrients in The Great Lakes	(EP-029)
Eating Like a Bird	(EP-030)

OEAGLets

In the primary grade range we have three activities. All use Lake Erie information applied to all primary subject areas.

Lake Erie — Take a Bow	(EP-031)	$5.00
Build a Fish to Scale	(EP-032)	$5.00
A Day in the Life of a Fish	(EP-033)	$5.00

Additional Educational Materials

Supplemental Curriculum activities to Accompany Holling C. Holling's *Paddle-To-The-Sea*	(EP-076)	$10.00
Holling C. Holling's *Paddle-To-The-Sea*	(EP-076/B)	$10.00
The Ohio Sea Grant Education Program: Development, Implementation, Evaluation	(EP-075)	$8.00
Sea Grant's Marine Education Bibliography		free
Abstracts of Research in Marine and Aquatic Education: 1975-1990	(EP-077)	$4.00
Great Lake Erie	(EP-079)	$10.00

Make payment payable to The Ohio State University in U.S. dollars.
Mail your request and payment to:
Ohio Sea Grant Publications, The Ohio State University, 1314 Kinnear Road, Columbus, OH 43212-1194

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